THE UNIVERSITY OF ALBERTA

INDUSTRIAL WATER USE IN EDMONTON

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled Industrial Water Use in Edmonton, submitted by Gail Herscovitch in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

This thesis concerns industrial water use in Edmonton. Since Edmonton receives surplus water from the mountain and foothill region of the Rocky Mountains, the quantity of surface supplies in the mountain and foothill region as well as in the immediate vicinity of Edmonton are discussed in terms of the parameters important to water supply: precipitation and evapotranspiration. Quality of water supply is considered in relation to analyses of water samplings from the North Saskatchewan River at Edmonton and further downstream. The quantity and quality of groundwater supplies is also discussed. Methods for the improvement of regime, quality, and increase in yield are considered.

Water demands for the Edmonton area are outlined and more detailed attention is given to industrial demand in the City. Most of the plants receive water from the municipal distribution system, but those located on the outskirts of the city, as well as those in Strathcona, require water from additional sources. Very few plants, mainly those involved in the construction industry, indicate seasonality in operation. The petroleum industry, with plants located in Strathcona, has the largest water demand. In general, firms are satisfied with the quality of supply, but a few, most of which receive their supply from sources other than the municipal system, do carry out intake treatment.

In relation to major industrial areas, Edmonton has a rather low industrial water demand, as indicated by the

proportion of the intake used for human requirements and for boiler feed. Waste treatment is not widely practised as most industries discharge to the municipal sewer system which provides treatment. The industries on the outskirts of the city, particularly in Strathcona, discharge waste to other outlets and generally do carry out treatment. This is particularly true of the petroleum industry which has the highest waste discharge, but which also carries out waste treatment to the highest degree.

In general water supply is adequate for present industrial demand in Edmonton, both in quantity and quality. Downstream from Edmonton, however, the quality of water is considerably lower and may prove a deterrent to industrial development.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

There exists today an awareness that unlimited and careless uses of our natural resources should be practices of the past. We must expand our efforts so as not to deplete our renewable natural resources, and we must use these resources to full advantage.

In most cases water resources are for common use. Since our sources of water must serve many users and provide for a sequence of uses, water should be considered as a loan to be returned for additional use with as little reduction in quantity and impairment in quality as is consistent with good conservation controls and techniques.[1] We must, therefore, plan for intelligent development, utilization and conservation of our local and regional water resources in line with established and anticipated needs. Water resources are needed for many facets of our activities: for domestic use; industry; navigation; fishing; bathing and recreation; agriculture; irrigation; electric power; forestry; waste disposal; etc.

Water is an essential raw material for industry. It is used for cooling, processing, chemical combinations, washing, boiler feed, fire protection, and sanitary and service use. Water is said to be used in greater amounts than any other product and to constitute in volume the main

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[1] J.B. Graham and M.F. Burrill (eds.), Water for Industry. American Association for the Advancement of Science, Washington, D.C., 1956, p. iii.

component of all material resources required by industry.[2] This is an economic factor of great importance. Many types of industry cannot survive long in an area where water supply is inadequate in quality or quantity.[3]

For example, the water quality tolerance for brewing purposes is as follows: 10 p.p.m.-turbidity; 75 p.p.m.-alkalinity; pH content - 6.5-7; total solids - 500 p.p.m.; Iron and Mn content - 0.1 p.p.m. Water quality tolerance for dyeing is: 5 p.p.m. - turbidity; 5-20 p.p.m. - colour; 20 p.p.m. - hardness ($CaCO_3$); Iron and Mn content - 0.25 p.p.m.[4] It takes approximately 10,000 gallons of water to produce one ton of steel, and 8,000 to 17,000 gallons of water to dye 1,000 pounds of cotton goods.[5]

The basic problems of industrial water use and supply and disposal of industrial waste by water have not been accorded much attention in Canada. The work of Harold A. Leverin, Industrial Waters of Canada, reports on the quality of waters examined from 1934 to 1943. During the

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[2] Loc. cit.

[3] "Industry", for the purposes of this paper, is defined as that part of industrial activity which produces tangible goods. This is unlike service industries which produce services. It does not include enterprises such as agriculture, mining, and construction which also produce tangible goods. These industries are eliminated by their methods and processes and also by the fact that, unlike manufacturing, they are not confined to factory production. The industries included in this study are those included in the Standard Industrial Classification Manual of the Dominion Bureau of Statistics.

[4] L. Klein, Aspects of River Pollution, London, 1957, p. 105.

[5] G.E. Symons, "Industrial Waste Disposal". Sewage Works Journal, Vol. 17, No. 3, 1945, pp. 558-572.

early 1950s the Department of Mines and Technical Surveys put out a series of industrial water reports by J.F.J. Thomas concerning qualitative water analysis of important river drainage basins in Canada: the Saskatchewan River Drainage Basin; the Fraser River Drainage Basin; the Upper St. Lawrence River - Central Great Lakes Drainage Basin; etc. Hydrometric survey data of surface water supplies of Canada have been studied recently by the Department of Northern Affairs and National Resources. Water pollution studies and reports on local drainage areas have been done mainly in Ontario, but a few exist also for the provinces of New Brunswick, Quebec, Manitoba, Alberta, and British Columbia. Each year the Environmental Health Services Division of the Albertan Department of Health puts out a summary report of the North Saskatchewan River Pollution Survey.

Recently Prime Minister Trudeau and Treasury Board President C.M. Drury stated that technological advances which are of most direct benefit to society should be given priority in Ottawa's science program.[6] The six broad areas in which Canada will specialize are: space research; water resources research; human environment and ecology; transport; computer science and technology; and northern resources development. In addition, a Science Council report entitled A Major Program of Water Resources Research

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[6] J. Fraser, "Science Policy to Stress Six Areas of Broad Interest". The Edmonton Journal, October 7, 1968, p. 26.

in Canada was made public October 1st, 1968. This report outlined a set of recommendations, and stated that Canada must triple her annual expenditure of $8,400,000 on water resources research by 1972-73 and needs to devote that money to solving problems uniquely Canadian.[7]

It would prove useful to know the main sources of industrial water supply. We must find out if water supplies are sufficient to support major industrial expansion. We should also be aware of the volumes withdrawn by specific industries as well as the times peak supplies are needed. If they exist, the periods, durations, and volumes of water deficiency should be known. The capacity of water supply systems must be ascertained.

We must discover whether the quality of water is satisfactory as well as uniform throughout the year, the purposes for which industrial water is being used, and whether plants practise water conservation. It would be useful as well to know what proportion of the intake water needs to be treated, the type of treatment required, and the time treatment is required.

In addition we must learn what volumes of water are discharged annually and per month as well as the temperature of discharge water, and the type of treatment waste water is given, if any. We should know the point of disposal of discharged water, and we must ascertain whether the

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[7] R. Cohen, "More Industrial Research on Water Resources Urged". The Edmonton Journal, October 3, 1968, p. 8.

disposal of industrial wastes introduces a use of our water resource which is incompatible with other industrial and nonindustrial uses.

The nature of changes foreseen in water withdrawals, water quality, and waste water treatment in the near future should be ascertained. Necessary, too, are the dates of installation, expansion, and replacement of equipment for water supply and waste water treatment facilities, and their costs.

Data on industrial water use are particularly scant in the Prairie Provinces. Use patterns in this area are not necessarily the same as those elsewhere in Canada. The present study was conceived as an examination of water use in a rapidly developing area of the Prairies. The immediate objective of the study is to provide information about the nature of water supply, water quality, water use, waste water, treatment of waste water, and costs involved for the Edmonton area.

Edmonton is particularly suitable for such a study. In comparison to the main manufacturing areas of Canada, Edmonton is in a region of meager water resources. Cass-Beggs has studied the concentration of precipitation for settled and unsettled zones in Canada.[8] The settled area (34 per cent of the total area) receives 48.7 per cent of the total annual precipitation. The settled portion of

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[8] D. Cass-Beggs, "Water as a Basic Resource". Resources for Tomorrow. Conference Background Papers, Vol. 1, Ottawa, 1961, p. 174.

the Prairie Provinces which contains 32 per cent of the settled area of Canada and 11 per cent of the total territory receives only 19 per cent of the precipitation falling on settled areas and 9 per cent of all precipitation. A shortage of water for industrial purposes could defeat hopes for future growth and prosperity just as surely as a shortage of capital, raw materials, or labour. We must ascertain whether the water resources in the Edmonton area are adequate to meet future requirements of industrial growth.

In recent years there has been an increase in the proportion of Canadian manufacturing performed in the Prairie Provinces, particularly in Alberta. Major assets in attracting additional manufacturing industry to Edmonton are abundant petroleum and natural gas for raw material and cheap fuel, and a government and public which welcomes new investment. The discovery of oil in February, 1947, at the Leduc field, twenty miles south of the city, as well as subsequent discoveries, established Edmonton as the centre of Canada's oil production. The exploitation of these resources has widened the city's economic base. Oil refineries, petro-chemical industries, and others using natural gas or by-products were introduced. Major industries - cement, steel, plywood, resins, etc. - have been established to serve the oil industry, or as a result of increased construction. The gross value of manufactured products in the Edmonton metropolitan area

increased from about $121,000,000 in 1948 to $418,000,000 in 1958, and in 1965 the value of shipments of goods manufactured in Edmonton was over $537,000,000.[9,10]

There has been a rapid growth of Edmonton's population, induced by the development of oil and gas. Since 1947 well over half of the population increase has been due to immigration.[11] The rate of population increase between 1941 and 1951 placed Edmonton first among all census metropolitan areas in Canada with an increase of 76.9 per cent. Calgary, second in rank, had a growth rate of only 49.5 per cent. Since 1951 the city as a metropolitan area has grown an average of 16,000 persons a year with a varying annual percentage increase of 5 to 9 per cent.[12] In June 1968 the census metropolitan area had 420,290 persons, and this figure placed Edmonton as the fourth largest city in Canada.[13]

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[9] F. Marlyn and H.N. Lash, "The Edmonton District. A City Centered Multiple Resource Region". Resources for Tomorrow, Conference Background Papers, Vol. 1, p. 461.

[10] Alberta Bureau of Statistics, Alberta Industry and Resources, Edmonton, 1968, p. 21.

[11] W.C. Wonders, "Edmonton, Alberta. Some Current Aspects of its Urban Geography". Cdn. Geogr., No. 9, 1957, p. 14.

[12] Province of Alberta, Report of the Royal Commission on the Metropolitan Development of Calgary and Edmonton, Edmonton, 1956, Ch. 2, p. 4.

[13] Alberta Bureau of Statistics, Alberta Market Data, June 1968.

CHAPTER I

WATER SUPPLY

The city of Edmonton is located on the banks of the North Saskatchewan River. This river forms part of the Saskatchewan River basin which covers approximately 156,255 square miles of which 80,655, 67,195, and 8,405 square miles lie in the provinces of Alberta, Saskatchewan, and Manitoba respectively.[1] The basin is drained by the north and south branches and the main stem of the Saskatchewan River and their tributaries. The northern branch rises in the Rocky Mountains, east of the continental divide, along the Alberta-British Columbia border approximately 200 miles southwest of Edmonton. It is joined by the South Saskatchewan River at a point some thirty miles east of Prince Albert to form the Saskatchewan River. The Saskatchewan River flows into Lake Winnipeg, the waters of which drain into the Nelson River and are ultimately emptied into Hudson Bay.

In Alberta, the North Saskatchewan River and its tributaries have a total length of 2,200 miles and drain 36,050 square miles or 14.1 per cent of the area of the province.[2] The North Saskatchewan River cuts across the province from southwest to northeast. The river rises at an elevation some 5,000 feet above sea level and flows northeast to Edmonton at which point it is some 2,000 feet above sea

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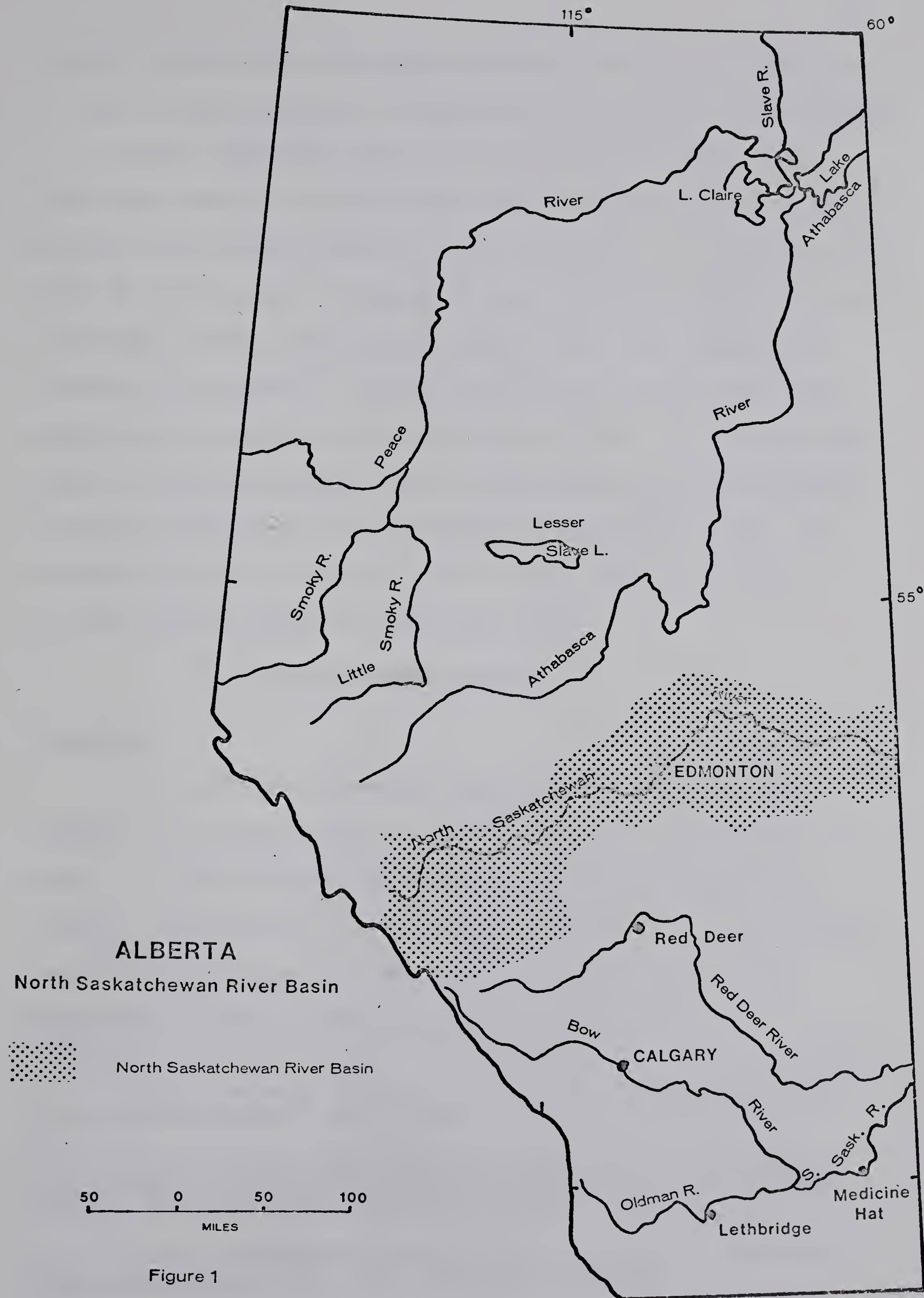
[1] J.F.J. Thomas, Industrial Water Resources of Canada. Ottawa, 1956, p. 6.

[2] Loc. Cit.



ALBERTA
North Saskatchewan River Basin

Figure 1

level. By the time the river reaches the city of Edmonton it has drained an area of approximately 10,500 square miles.

In the Edmonton area the river valley is deep and twisting, ranging in width from half a mile in the southwest to one and one-half miles in the northeast. It averages 160 feet in depth, but in places is approximately 200 feet deep.[3] The slope of the river banks varies from five degrees to forty-five degrees.[4] Several tributary ravines enter the main valley from the north and south sides. With the exception of Whitemud Creek, these tributaries are intermittent. The main tributaries are Whitemud Creek, Mill Creek, and Fulton Creek on the south side of the valley, and Groat Ravine and Rat Creek on the north side.

SURFACE WATER SUPPLIES

Quantity

The climatic parameters important to surface water supply are precipitation, temperature, and evaporation. As early as 1905 Transeau constructed a precipitation-evaporation ratio map of the Eastern United States.[5] The ratios were based on Russell's evaporation measurements from a free-water surface made during 1877-1878.

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[3] W.C. Wonders, "River Valley City - Edmonton on the North Saskatchewan". Cdn. Geogr., No. 14, 1959, p.8.

[4] W.J. Hozack, The Relative Importance of Site and Situation in the Urban Geography of Edmonton. typewritten report, University of Alberta, Edmonton, 1968, p. 8.

[5] E.N. Transeau, "Forest Centres of Eastern America". Amer. Naturalist, Vol. 39, 1905, pp. 875-889.

Penck used precipitation and evaporation as a basis for his classification of climates.[6] He set the boundary between arid and humid regions at that area where precipitation (P) and evaporation power (E) are equal and arrived at the following general groups:

E greater than P: arid regions;

E equal to P: arid-humid boundary;

E smaller than P: humid regions.

As a substitute for the precipitation-evaporation ratio, which is difficult to determine, Lang suggested the precipitation-temperature ratio (millimeters: degrees centigrade). Lang's rain factor = $\frac{P}{T}$.[7]

De Martonne has attempted to correlate soil features with precipitation factors.[8] De Martonne's indice d'aridité = $\frac{P}{T + 10}$. P represents the annual precipitation in millimeters, and T the annual temperature in degrees centigrade.

A commonly-used substitute for the precipitation-evaporation ratio is Meyer's NS quotient which is obtained

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[6] A. Penck, Versucheiner Klimaklassifikation auf Physiogeographischer Grundlage, Berlin, 1910, 239 pp. Discussed by Hans Jenny, Factors of Soil Formation - A System of Quantitative Pedology, New York, 1941, p. 107.

[7] R. Long, "Verwitterung und Bodenbildung als Einfuhrung in die Bodenkunde", E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1920. Discussed by Hans Jenny, ibid, p. 108.

[8] E. de Martonne, "Aréisme et Indice d'aridité", Comptes Rendus, Academie des Sciences, Paris, Vol. 182, 1926, pp. 1395-1398.

by forming the ratio:

$$\frac{\text{Precipitation (millimeters)}}{\text{Absolute saturation deficit of air (millimeters mercury)}}.$$ [9]

In the United States the NS quotient parallels the Transeau ratio quite closely over a wide moisture range. In Australia, Prescott observes a constant relationship between evaporation and saturation deficit that permits the calculation of the Transeau value by dividing the NS quotient by the factor 230.[10,11] NS quotient maps have been published for Europe, the United States, Australia and India.

Thornthwaite has proposed a moisture classification that is based on a summation of monthly moisture values.[12] This "precipitation effectiveness index" may be calculated with the aid of the formula

$$I = \sum_{n=1}^{n=12} 115 \left(\frac{P}{T - 10} \right)_n^{10/9}$$

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[9] A. Meyer, "Uber Einige Zusammerhange Zwischen Klima und Boeden in Europa". _Chemie der Erde_, Vol. 2, 1926, pp. 209-347. Discussed by Hans Jenny, _op. cit._, pp. 109-111.

[10] J.A. Prescott, "Single Value Climatic Factors". _Trans. of the Royal Society of South Australia_, Vol. 58, 1934, pp. 48-61. Discussed by Hans Jenny, _op. cit._, p. 109.

[11] Idem, "The Soils of Australia in Relation to Vegetation and Climate". _Council for Scientific and Industrial Research, Australia_, Bulletin 52, 1931. Discussed by Hans Jenny, _op. cit._, p. 109.

[12] C.W. Thornthwaite, "The Climates of North America". _The Geographical Review_, Vol. 21, 1931, pp. 633-654.

where P = monthly precipitation in inches;

T = monthly temperature in degrees Fahrenheit;

n = number of months.

In the study area precipitation occurs in the form of rain as well as snow. The average annual precipitation at Edmonton is 18.25 inches of which 65 per cent falls during the growing season. The annual range of precipitation based on data from 1927 to 1967 indicates the lowest annual precipitation at 12.25 inches in 1961 and the highest at 23.75 inches in 1942. The annual range of snowfall during this period was from 33.3 inches in the winter of 1940-41 to 89.4 inches during the winter of 1964-65. The maximum water supply occurs in summer; however, much of this evaporates. Snowfall is important due to melting and resultant surplus water supplies in spring.

Edmonton looks to the mountain and foothill area for its main source of water supply.[13] Although the region falls within one climatic classification on a world-scale, the climate is, in fact, heterogeneous, being complicated by local factors of elevation, slope, aspect, ground cover and exposure. Since a precise definition of each local climate is not likely to be achieved, it has been found practical to determine in detail the climate of key locations, and to apply this knowledge to similar and adjacent areas. General similarities have, however, been

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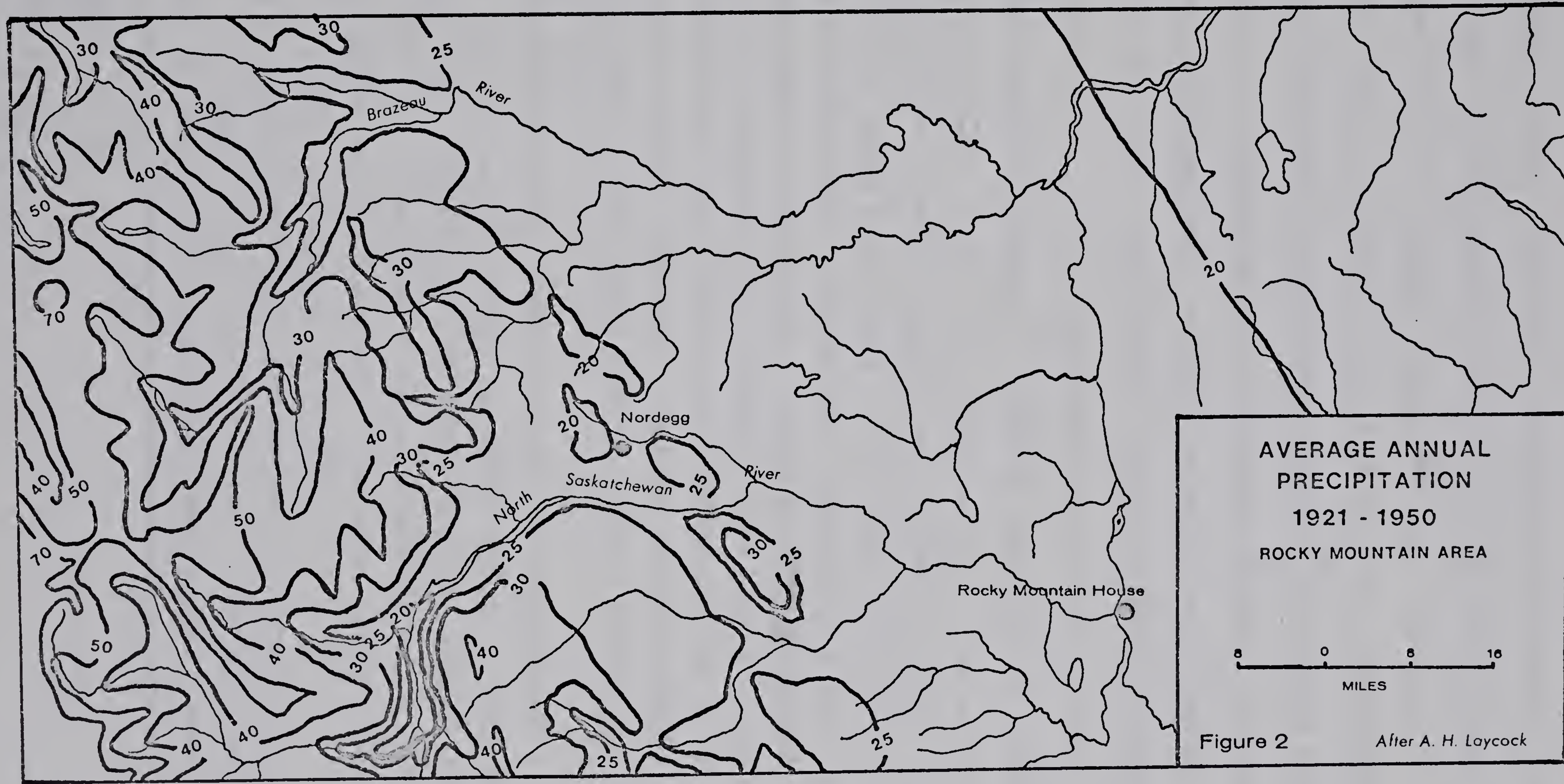
[13] A.H. Laycock, Precipitation and Streamflow in the Mountain and Foothill Region of the Saskatchewan River Basin. Prairie Provinces Water Board Report No. 6, Regina, 1957, p. 1.



AVERAGE ANNUAL PRECIPITATION 1921 - 1950
ROCKY MOUNTAIN AREA

Figure 2 After A. H. Laycock

observed in this area. Heavier precipitation occurs in the back range than in the eastern areas; in the front range and foothill areas than in eastern intermontane valleys or plains areas; and in the more elevated than in the low-lying areas.[14] The high back range areas generally receive well over 50 inches of precipitation per annum whereas the low-lying eastern intermontane valleys receive less than 25 inches. Each year has significant local variations (Figure 2).

The pattern of seasonal precipitation varies within the mountain and foothill region.[15] Winter snowfall is greater than summer rainfall in the back range areas. The eastern mountain areas have greater spring and summer rainfall than winter snowfall, except perhaps in the most elevated sections. The precipitation regime has a pronounced spring and early summer peak on the eastern slope and front ranges and these rains vary appreciably in amount. Rainfall is usually greatest in May and early June in the south and in late June and July in the north. Snowfall appears to be a slightly larger proportion of the total precipitation in the south than in the north.

At Edmonton the mean annual range of temperature is 55°F. The highest temperatures normally occur in July and August. The mean temperature for July for the period 1927 to 1967 is 63.1°F. The lowest temperatures normally occur from mid-December to mid February. The mean temperature from 1927 to 1967 for January is 6.3°F.

Data for Nordegg are representative of temperature conditions in the mountain and foothill area. Monthly temperature normals of mean daily temperature averaged between 1931

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[14] *Ibid.*, p. 3.

[15] *Ibid.*, p. 6.

and 1960 indicate the lowest monthly normal to be in January at 10.7°F. The highest mean monthly normals occurred in July with 55.1°F. being recorded.

Between periods of rain, water is given up in a twofold drying process. Direct evaporation occurs from water surfaces, intercepted moisture, and from the soil. In addition plants draw soil moisture into their systems through vast networks of rootlets. This water, after being carried upward through the trunk and branches into the leaves is discharged in the form of water vapor, through leaf stomata, into the atmosphere, a process called transpiration. The term evapotranspiration is used to cover the combined moisture loss from direct evaporation and the transpiration of plants. In general, the less moisture remaining in the soil, the slower is the loss through evapotranspiration. Consequently, two forms of evapotranspiration have been defined. Potential evapotranspiration is the maximum loss of water possible under complete plant cover assuming continued supply to the soil of all the water which the plants can use and the soil pores can hold. Actual evapotranspiration is the true or observed quantity of evapotranspiration, decreasing in rate as the moisture supply is depleted.

Precipitation and temperature are easily measured and have been recorded in most settled areas of the world. It is not easy to measure evapotranspiration, however. The little we know about its areal distribution has been pieced together from scattered means. Various methods have been

used in attempts to measure this factor.

The best known direct method of measuring natural evapotranspiration is by means of lysimeters. This method is very practical even though it has artificial conditions created by edge effects and interruption of the soil column. Sap velocity rates may be used as an index of transpiration.[16] This method has been found satisfactory on an individual tree basis but is plagued by a difficult sampling problem in trying to provide estimates of total actual transpiration by area. The tent method gives good qualitative results but transpiration rates are influenced by the greenhouse effect of the plastic material used.[17] This method is also limited in the size of vegetation which can be studied. The quick weighing of newly severed branches has been widely used in the U.S.S.R.;[18] in England[19]

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[16] C.M. Skau and R.H. Swanson, "An Improved Heat Pulse Velocity Meter as an Indicator of Sap Speed and Transpiration". Journ. Geophysical Research, Vol. 68, No. 16, 1963, pp. 4743-4749.

[17] J.P. Decker, W.G. Taylor and F.D. Cole, "Measuring Transpiration of Undisturbed Tamarisk Shrubs". Plant Physiology, Vol. 37, No. 3, 1962, pp. 393-397.

[18] Aleksandr Alekseevich Molchanov, The Hydrological Role of Forests. Jerusalem, 1963.

[19] A.J. Rutter, "Evaporation From a Plantation of Pinus Sylvestris in Relation to Meteorological and Soil Conditions". C.R. Ass. Int. Hydrologie Sci., Hannover Symp., Vol. 1, 1959, pp. 101-110. This article is discussed by W.W. Jeffrey, Vegetation, Water and Climate: Needs and Problems in Wildland Hydrology and Watershed Research, Calgary, 1965, p. 126.

and in Israel,[20] this method has also been tried. As with other techniques, difficulty arises in sampling and in extrapolation to an area basis, in addition to the basic question of the effect of twig severance on the quantitative weight recorded.

Indirect methods based upon heat budget and turbulent diffusion of water vapor have been increasingly used in recent years. This approach, as exemplified by Suomi and Tanner (1958), consists of measuring net radiation, soil heat flux, and air temperature and vapor pressure gradients over a vegetative surface.[21] An equation is developed in which the only unknown is latent heat flux, which is used to compute evaporation. This method involves a complexity of instrumentation and in forest cover the difficulty of raising them above the foliar surface.

Thornthwaite has developed methods for finding potential evapotranspiration.[22] His procedures as developed in 1948 are used in this study. According to the Thornthwaite method, if precipitation and soil moisture storage capacity and vegetative cover are known, then actual

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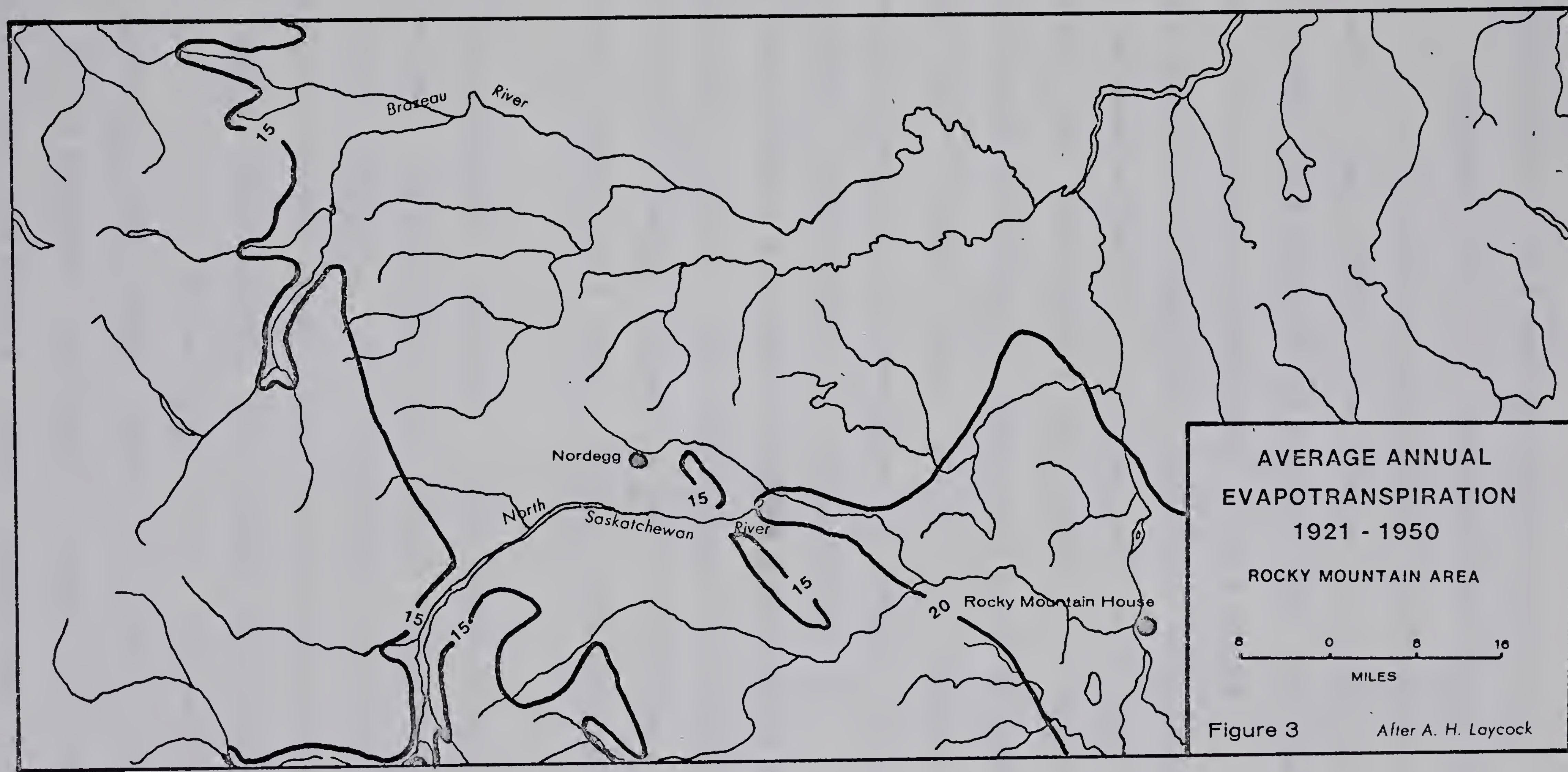
[20] H.R. Oppenheimer, "An Experimental Study on Ecological Relationships and Water Balance of Mediterranean Forest Vegetation". Pales. Journ. Botany, Vol. 8, 1953, pp. 103-124. Discussed by W.W. Jeffrey, loc. cit.

[21] V.E. Suomi and C.B. Tanner, "Evapotranspiration Estimates From Heat-Budget Measurements Over a Field Crop". Trans., Amer. Geophysical Union, Vol. 39, No. 2, 1958, pp. 298-304.

[22] C.W. Thornthwaite, "An Approach Toward a Rational Classification of Climate". Geogr. Review, Vol. 38, 1948, pp. 55-94.


AVERAGE ANNUAL
EVAPOTRANSPIRATION
1921 - 1950
ROCKY MOUNTAIN AREA
8
0
8
16
MILES
After A. H. Laycock
Brazeau River
North Saskatchewan River
Nordegg
Rocky Mountain House
15
15
15
15
15
15
20
Figure 3

evapotranspiration can be found by using book-keeping procedures. Procedures such as Thornthwaite's based on latitude, and on a few climatic parameters available over a long period of time, checked over large parts of the world for accuracy and reduced to tabular form for ease of calculation have distinct advantages. While these computations are purely empirical they give a good insight into water balance patterns in an area, and have been found to agree rather well with direct measurements of evapotranspiration made in irrigated areas, and with estimates derived from data on stream flow. Methods for finding potential evapotranspiration developed by Penman, Turc, Budyko and others require detailed measurements of parameters unobtainable for many stations and require much dull computational labour. The added degree of refinement acquired is lost by changes caused in local conditions when data have to be transferred from a distant meteorological station.

Data from 1921-1950 show that in the Edmonton area average potential evapotranspiration ranges from twenty to twenty-two inches annually. In the mountain and foothill region average potential evapotranspiration ranges from sixteen to twenty inches a year, this factor being higher in the foothills than in the mountain area. The average actual evapotranspiration around Edmonton is sixteen inches per annum. In the mountain and foothill region the range is from fourteen to sixteen inches a year (Figure 3).

TABLE I - WATER SUPPLY FOR THE EDMONTON AREA

Year	Factor	J	F	M	A	M	J	J	A	S	O	N	D	Year
1965	T°F	3.7	9.7	16.7	37.5	50.1	57.8	65.4	64.5	43.4	47.4	19.5	13.5	--
	PE"	--	--	--	.69	2.79	4.08	5.34	4.88	1.59	1.66	--	--	21.03
	Ppt"	2.00	1.02	.45	.64	2.90	7.48	2.11	2.14	1.10	.22	.71	.66	21.43
St (2.17")*		4.00	4.00	4.00	3.95	4.00	4.00	.77	--	--	--	.71	1.37	--
Surplus,in.		.17	1.02	.45	--	.06	3.40	--	--	--	--	--	--	5.10
Deficit,in.		--	--	--	--	--	--	--	1.97	.49	1.44	--	--	3.90
1966	T°F	-8.3	13.4	24.5	33.7	54.3	56.8	62.9	59.7	56.3	41.0	15.5	14.1	--
	PE"	--	--	--	.35	3.59	4.08	4.93	4.13	3.18	1.10	--	--	21.36
	Ppt"	1.39	.50	.20	.73	1.11	.89	2.45	6.44	.34	.28	.66	.47	15.46
St (1.37)*		2.76	3.26	3.46	3.84	1.36	--	--	2.31	--	--	.66	1.13	--
Surplus,in.		--	--	--	--	--	--	--	--	--	--	--	--	--
Deficit,in.		--	--	--	--	--	1.83	2.48	--	.53	.82	--	--	5.66
1967	T°F	4.6	15.5	14.7	31.7	51.0	57.7	64.1	66.2	60.8	42.6	28.4	14.3	--
	PE"	--	--	--	--	2.79	3.66	4.93	4.88	3.50	1.10	--	--	20.86
	Ppt"	1.03	.78	1.22	.53	1.58	1.72	2.02	2.93	.03	1.61	.91	1.02	15.38
St (1.13")*		2.16	2.94	4.00	4.00	2.79	.85	--	--	--	.51	1.42	2.44	--
Surplus,in.		--	--	.16	.53	--	--	--	--	--	--	--	--	.69
Deficit,in.		--	--	--	--	--	--	2.06	1.95	3.47	--	--	--	7.48
1968	T°F	4.3	19.5	34.0	40.0	52.1	58.1	63.1	58.2	51.7	43.2	24.5	13.3	--
	PE"	--	--	.31	1.38	3.19	4.08	4.93	3.75	2.54	1.38	--	--	21.56
	Ppt"	.99	.19	.39	.66	.10	2.14	3.08	3.34	1.47	.50	.88	.99	14.73
St (2.44")*		3.43	3.62	3.70	2.98	--	--	--	--	--	--	.88	1.87	--
Surplus,in.		--	--	--	--	--	--	--	--	--	--	--	--	--
Deficit,in.		--	--	--	--	.11	1.94	1.85	.41	1.07	.88	--	--	6.26

Sources: C.W. Thornthwaite and J.R. Mather, Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Publications in Climatology, Vol. 10, No. 3, Centerton, New Jersey, 1957, pp. 185-311; and Canada, Dept. of Transport, Meteorological Branch, Monthly Records, Toronto.

T = temperature; PE = potential evapotranspiration; Ppt = precipitation

St = storage; * = moisture in storage at start of year.

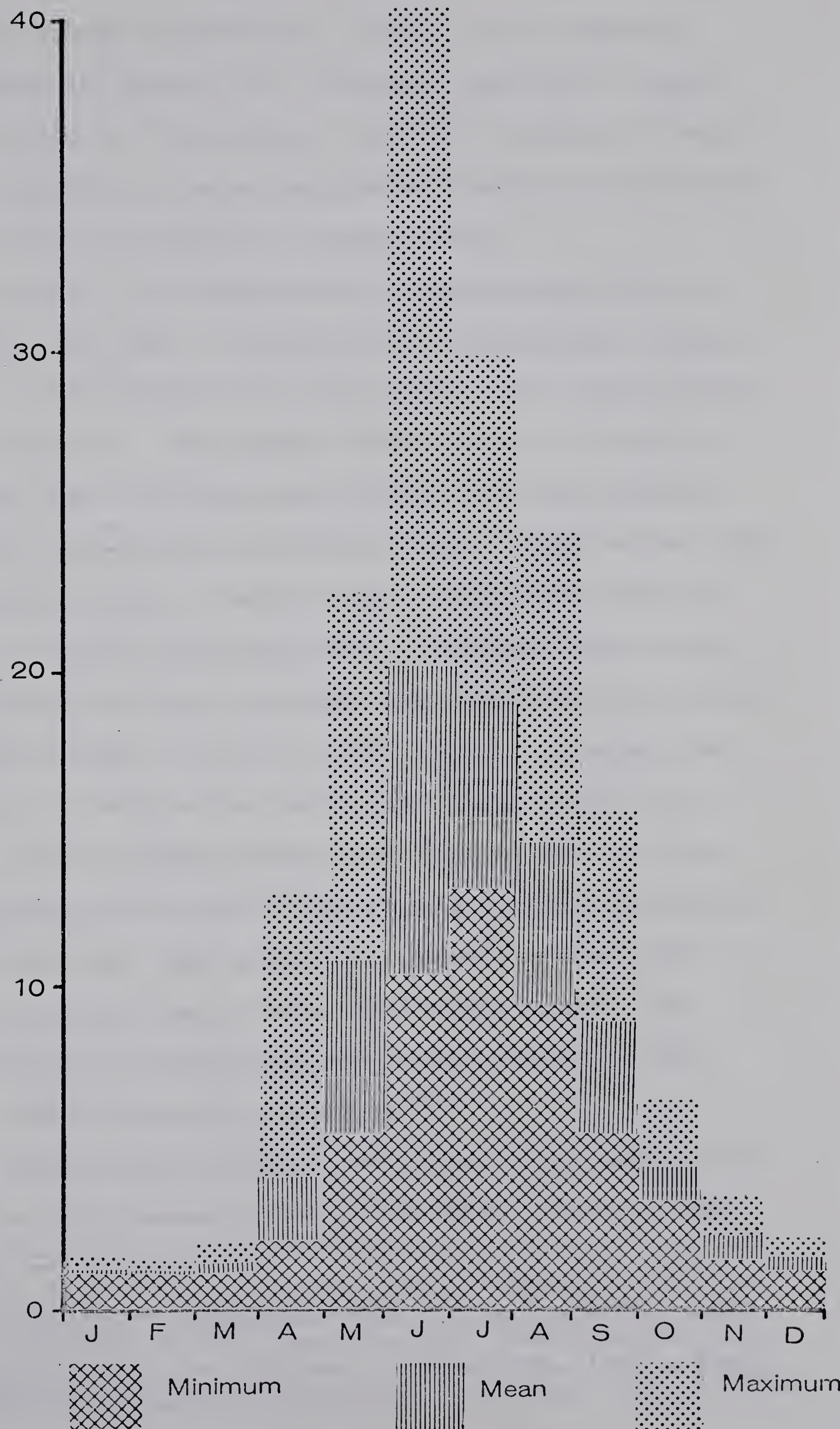
Figures for October 1968 are estimated; those for November and December 1968 are averages.

Figure 5

NORTH SASKATCHEWAN RIVER AT EDMONTON

Average Monthly Flow, 1920 - 1960

c.f.s. x 10^{-3}



The Thornthwaite procedures (1948) for the Edmonton area are shown in Table I, in a tabular form, for a representative period of four years. Data for a series of years illustrate features of water surplus and deficit that cannot readily be shown in single or average years.

Like rainfall and temperature, evapotranspiration is not generally the same in amount or in distribution through the year. In some places more rain falls than the soil and vegetation can use. The surplus water moves as interflow and overland flow to streams and rivers. In other places precipitation is less than potential evapotranspiration, and a water deficit occurs. Regions with alternating wet and dry seasons, or with cold seasons of low water need, such as the Canadian prairies, normally show three features which can be seen in Table I: (1) a period of full storage, when precipitation exceeds water need, and a water surplus accumulates; (2) a drying period, when stored soil moisture and precipitation are used in evapotranspiration, storage is steadily diminished, the actual evapotranspiration falls below the potential, and a water deficiency occurs; and (3) a moistening season when precipitation exceeds water need, and soil moisture is recharged.[23]

The average yearly surplus available for streamflow in the Edmonton area, based on data from 1921 - 1950, is one

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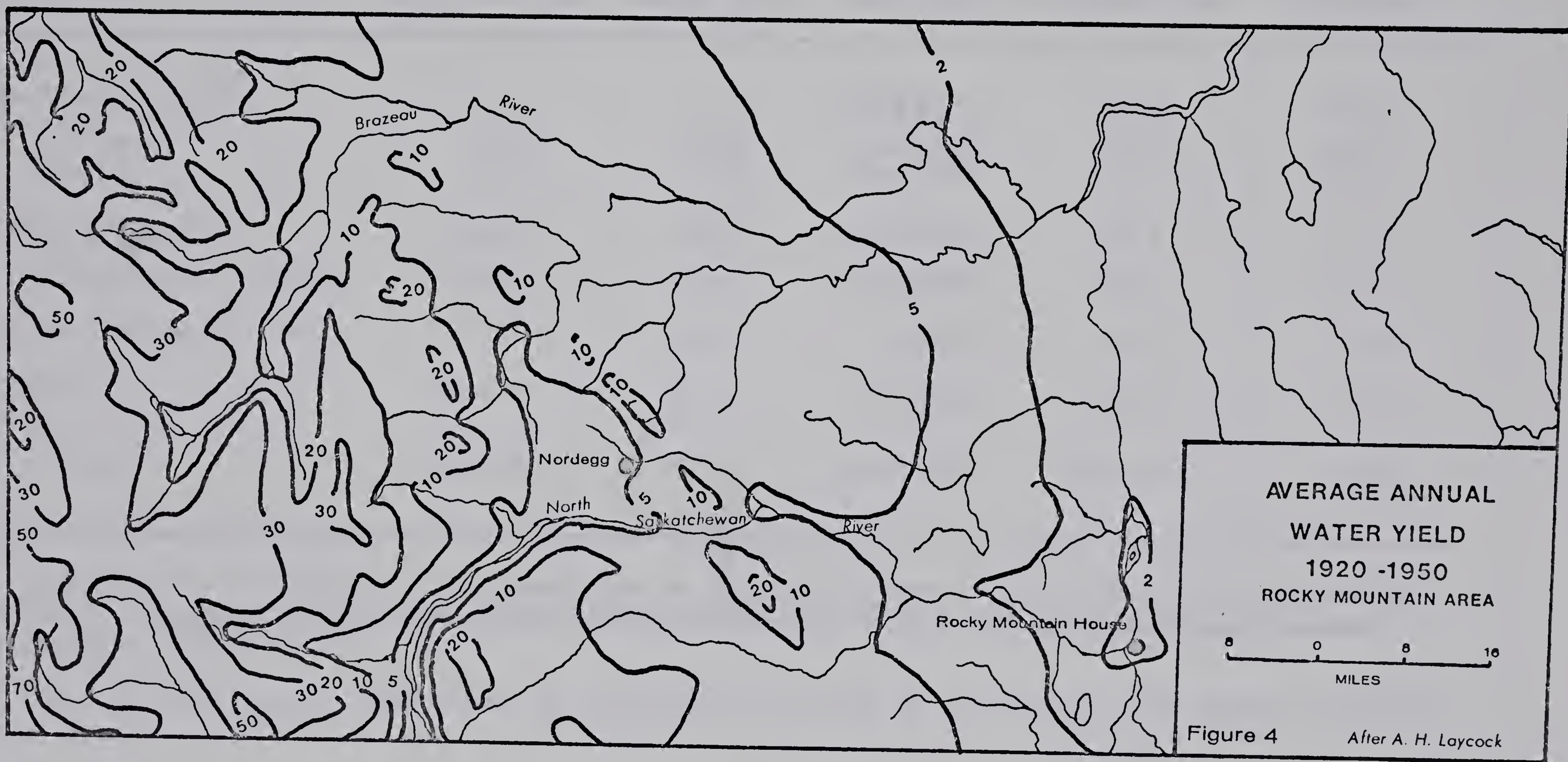
[23] C.W. Thornthwaite and F.K. Hare, "Climatic Classification in Forestry". Unasylva, Vol. IX, No. 2, 1955, pp.50-59. Also discussed by C.W. Thornthwaite, "Modification of Rural Microclimates", in William L. Thomas, Jr. (ed.), Man's Role in Changing the Face of the Earth. Chicago, 1956, p. 573.

inch. In the foothills surpluses of four and eight inches occur. Annual water yields of twenty and thirty inches are common in the mountains and yields of fifty and seventy inches per year are normal in the back ranges (Figure 4). The mountain and foothill portion of the North Saskatchewan Basin provides the greater part of the streamflow of the plains of the Prairie Provinces. In a relatively dry year, such as 1948-49, the plains portion of the North Saskatchewan Basin, with over 87 per cent of the area, contributed less than 16 per cent of the flow. The mountain and foothill National Parks and Forest Reserves contributed the greater part of the flow (see Table II). In addition to being greater, this flow is more dependable, has a better regime, is less subject to flooding, and has a better quality than that of the plains.

The hydrograph in Figure 5 represents the average monthly maximum, minimum, and mean flow of the North Saskatchewan River at Edmonton for the period 1920-1960. One of the features of the North Saskatchewan River is its great seasonal fluctuation in flow. The hydrograph indicates two types of runoff. First, during the early spring, the melting snow fills the streams and drainage courses of the prairie and foothills areas. Second, the precipitation which has been stored as snow in the mountains during the winter melts in the late spring and early summer causing peak flows in the streams and drainage courses of the area. At Edmonton, maximum flows occur most frequently in June and July. The peak daily discharge was recorded on June 28th, 1915 as



AVERAGE ANNUAL WATER YIELD 1920 -1950 ROCKY MOUNTAIN AREA

Figure 4

TABLE II - STREAMFLOW OF THE NORTH SASKATCHEWAN RIVER, 1948-1949

Source Area	Area in square miles	% of Basin Area	Streamflow, acre-feet	% of Total Streamflow	Water Yield in inches
A. National Parks	1,336	2.8	1,300,000	32.6	18.2
Jasper	445	0.9	350,000	8.8	14.7
Banff	891	1.9	950,000	23.8	20.0
B. Forest Reserve	4,468	9.4	1,944,000	48.7	8.1
Clearwater Forest	4,468	9.4	1,944,000	48.7	8.1
C. Other Foothills (a)	223	0.5	40,000	1.0	3.4
D. Plains	41,473	87.3	626,000	15.7	0.3
Total	47,500	100.0	3,910,000	100.0	1.5

Source: A.H. Laycock, "The Need for a Regional Approach in Watershed Management Planning". *Proceedings of the First Annual Meeting of the American Water Resources Association*, 1965, p. 147.

(a) = Areas over 4,000 feet in elevation outside of the Parks and Forest Reserve.

204,500 c.f.s., nearly 1,000 times that of the minimum daily flow. During the occasion the river rose forty-five feet and covered the entire floor of the river valley. River flow is generally lowest in January and February. The all time low occurred January 1st, 1940, when a flow of only 220 c.f.s. was registered. It is generally thought that this low flow was the result of an ice-jam upstream from Edmonton. In 1965, the average monthly range was from 2,100 c.f.s. in January to 38,500 c.f.s. in July. This represents a variation of over eight feet in the river height.

Immediately upstream from Edmonton, the North Saskatchewan River is usually ice-covered for four and one-half months of the year. Ice begins to form in early November. Complete coverage is not realized until December, with break-up most often occurring in mid-April. During this stage there are generally about eight feet of water in the river bed opposite the city power plant. An open channel is maintained for almost twelve miles downstream due to the releasing of cooling waters and industrial wastes at temperatures well above that of the river in winter.

In 1961 the Brazeau River Dam came into operation. Essentially a hydro-electric installation, this dam increases winter flow in the river. It raises the minimum daily flow during the winter from less than 1,000 c.f.s. to over 1,500 c.f.s. The ultimate storage capacity of the Brazeau Dam is 93,000 acre-feet. It was hoped to control the pollution factor by raising the minimum daily flow from less than

1,000 c.f.s. to over 1,500 c.f.s.[24] It was during the winter that pollution was most serious because low flows were insufficient to oxygenate the water and kill bacteria.

Quality

Data are collected each year by the Department of Health, of the Province of Alberta, to assess river quality. Over 140 samples were taken on the North Saskatchewan River during the period from October 11, 1967 to April 5, 1968 to determine river quality during periods of minimum flow. Eleven location sampling stations were used: Brazeau Reservoir discharge; Drayton Valley; Devon Bridge; 105 Street Bridge (Edmonton); Fort Saskatchewan Bridge; Vinca Ferry; Waskatenau; Duvernay Bridge; Elk Point Bridge; Lindbergh; and Lloydminster Ferry. Since the major pollutional load to the North Saskatchewan River occurs in the Edmonton area, a greater sampling frequency was conducted downstream. Upstream samples were collected on a monthly basis; near Edmonton, samples were collected generally on a weekly basis; and bi-weekly samples were collected farther downstream (Waskatenau, etc.). See Figure 6.

In this study, pollution is defined as anything causing objectionable conditions in any watercourse and adversely affecting any use or uses to which the water thereof may be put. There are many different kinds of pollution found in

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[24] J.L. Reid and K.G. Brittain, "Design Concepts of the Brazeau Development Including River and Hydrology Studies". *Engineering Journal*, Vol. 45, 1962, p. 62.

North Saskatchewan River Basin
ALBERTA
POLLUTION SAMPLING STATIONS
ON THE
NORTH SASKATCHEWAN RIVER

Figure 6

sewage and industrial wastes. For convenience a classification considering chemical, physical, physiological, and biological pollution will be discussed.[25]

Chemical pollution may be divided into two types: organic (carbon compounds) and inorganic (mineral compounds). Organic pollution is an extremely common form due to the presence of proteins, fats, carbohydrates, and other organic substances found in sewage and industrial wastes. Among the industrial wastes containing proteins are food processing and canning wastes, gelatin and glue manufacturing wastes, slaughtering, dairy, and tannery wastes. Fats occur in such industrial wastes as wool scouring, edible oil and fat refining, soap manufacture, and laundry wastes. Carbohydrates are found in paper and textile waste waters. Oil as a form of river pollution may be derived from industrial wastes, metallurgical industries, engineering works, garages, etc. Other organic pollutants are waxes, resins, tar, coal, dyes, and synthetic detergents. Many wastes contain poisonous organic compounds (such as phenols, tar bases, cyanides, and DDT) which not only kill bacteria and so render a river sterile and unable to undergo self-purification, but also cause mortality to fish and other aquatic life.

Table III presents some findings of the North Saskatchewan River Pollution Survey, 1967-1968.

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[25] For a more detailed discussion of the "Nature and Effects of Pollution" the reader is referred to: L. Klein, River Pollution, II, Causes and Effects, Butterworths Scientific Publications, London, 1962, pp. 22-109.

TABLE III - AVERAGE VALUE OF RIVER COMPONENTS, 1967-1968

Component	105 Street Bridge	Fort Saskatchewan	Duvernay Bridge	Lloydminster Ferry
Dissolved Oxygen mg/l.	12.63	11.39	9.79	9.86
Biochem. Oxygen Demand mg/l.	1.34	3.00	2.09	2.30
Oils and Greases mg/l.	0.32	1.04	--	0.64
Phenols p.p.b.	1.72	3.52	5.33	3.50

Source: Alberta Department of Health, adapted from Summary Report, North Saskatchewan River Survey 1967-68.

Generally the dissolved oxygen remained above the guide lines of acceptability (5 mg/l.). This is attributed to a mild winter and increased amounts of open water. Samplings at 105th Street Bridge showed dissolved oxygen levels to range from 11.2 mg/l. to 13.7 mg/l. Low values occurred in January at Duvernay Bridge, Elk Point Bridge, and Lloydminster Ferry. The values were 5.9 mg/l.; 4.8 mg/l.; and 5.4 mg/l. respectively. The highest average values for biochemical oxygen demand occurred at Fort Saskatchewan, and indicate an increase of approximately 2 mg/l. over the 105th Street Bridge values. The maximum value, 7.7 mg/l., was from a sampling at Lloydminster Ferry. The lowest value recorded at Edmonton was 0.10 mg/l. Phenols at a level of 5 parts per billion are considered a nuisance. Maximum values for this factor at Edmonton, Fort Saskatchewan, Duvernay Bridge, and Lloydminster Ferry were 5 p.p.b., 9 p.p.b., 24 p.p.b., and

21 p.p.b. respectively. Oil is objectionable in the river not only from an aesthetic viewpoint, but also because it spreads to form a thin film on the surface and so tends to prevent re-aeration of the river water. Oil also tends to coat the gills of fish.

Inorganic or mineral pollution may be caused by industrial wastes containing corrosive acids and alkalis which can do extensive damage to a stream by breaking down its natural buffer system and changing its pH value. Industries producing large volumes of acid wastes are iron pickling, titanium dioxide manufacture, viscose rayon, cellophane, and chemical manufacturing. Industries producing large amounts of alkaline wastes are tanneries, wool scouring, and chemical manufacturing. There are many toxic inorganic substances. The commonest are free chlorine, chloramines, ammonia, hydrogen sulphide, soluble sulphides, and salts of many heavy metals (e.g. copper, zinc, chromium, lead, nickel, silver, mercury, uranium, etc.). Soluble salts commonly found in rivers and in discharges to rivers include chlorides, sulphates, nitrates, bicarbonates, and phosphates of sodium, potassium, calcium, magnesium, iron and manganese. Soluble salts of certain relatively non-toxic metals (e.g. iron, aluminum) may cause pollution in a river by reacting with the natural bicarbonate alkalinity to precipitate insoluble hydroxides. Insoluble organic materials, such as clay, chalk and gypsum are occasionally present in industrial wastes. They increase the turbidity

of a river.

Table IV represents average findings of the North Saskatchewan River Pollution Survey 1967-1968.

TABLE IV - AVERAGE VALUE OF RIVER COMPONENTS, 1967-1968

Component	105 Street Bridge	Fort Saskatchewan	Duvernay Bridge	Elk Point Bridge
Hydrogen Ion Concentration, pH	8.10	8.04	7.99	7.92
Alkalinity mg/l.	156.17	154.19	147.92	145.33
Total Hardness mg/l.	188.11	---	--	--
Chlorides mg/l.	1.06	3.52	22.73	10.73
Ammonia Nitrogen mg/l.	0.41	1.21	1.52	1.65
Sulphates as SO_4 mg/l.	60.22	62.27	62.71	65.14
Nitrate Nitrogen mg/l.	0.08	0.15	0.46	0.47
Total Phosphorus as PO_4 mg/l.	0.15	0.63	0.64	0.69

Source: Alberta Department of Health, adapted from Summary Report, North Saskatchewan River Survey 1967-1968.

The hydrogen ion concentration remained quite constant at all stations, and showed the water to be slightly alkaline, with alkalinity decreasing with distance downstream from Edmonton. The amount of chlorides recorded shows considerable variation. The large rise in chloride, and nitrate content downstream illustrate the presence and sudden increase in the amount of treated sewage effluents at Edmonton. The values of ammonia-nitrogen downstream from Edmonton were of

a magnitude considered to be excessive as well as detrimental to aquatic life. The presence of calcium chloride, sulphates, and phosphorus generally increased with distance downstream. Effluents having an excessive content of soluble salts (300 p.p.m.) are liable to cause corrosion of pumps, pipelines, and other structures made of metal or concrete.

Physical pollution includes colour, turbidity, temperature, suspended matter, foam and radioactivity. Many industrial wastes discharging to a river have a pronounced colour which they give to the water. In many instances the colour is caused by organic dyes, but there are some highly coloured substances of mineral origin (e.g. iron and chromium compounds). Colour in itself is not necessarily harmful. Colour was noted on a few occasions in the North Saskatchewan River Pollution Survey 1967-1968. However, data on colour for most samplings are not available.

Sewage and industrial waste waters have a degree of turbidity. Generally the more pronounced the turbidity, the stronger is the waste. However, the absence of turbidity does not necessarily imply that a river is unpolluted. A river might be turbid owing to the presence of small amounts of inert and relatively harmless material (e.g. clay) and still be satisfactory for fishing and other uses. Average values of turbidity as SiO_2 are 19.1 mg/l., 11.3 mg/l., and 13.9 mg/l. at 105th Street Bridge, Waskatenau, and Lloydminster Ferry respectively. The

maximum and minimum values recorded at 105th Street Bridge were 120 mg/l. and 3 mg/l.

The discharge of heated effluents and of large volumes of warm "cooling water" may cause a rise in temperature in a river. Some types of fish can become acclimatized to higher temperatures, but at a certain point they will die. If a rise in temperature occurs in a stream polluted by organic matter, disappearance of dissolved oxygen occurs due to the lower solubility of oxygen at the higher temperature, and an increased rate of utilization of dissolved oxygen by biochemical reactions. During the sampling period of the North Saskatchewan River Pollution Survey 1967-1968, water temperatures ranged from zero to eleven degrees centigrade. It might be useful if water temperature data could be collected during the summer.

Insoluble suspended matter may be organic or inorganic in character, or partly organic and partly inorganic. Suspended matter in sewage effluents and dairy wastes is largely organic in nature. Wastes from sand-washing and stone quarrying contain mainly inorganic suspended solids. Suspended solids interfere with self-purification of streams by diminishing photosynthesis. They damage fisheries and are unsightly. The presence of suspended matter has not been noted in the North Saskatchewan River Pollution Survey 1967-1968.

Foam consists of a dispersion of gas bubbles in a liquid medium. Many substances are known to cause foam in

water (e.g. soaps, synthetic detergents, fish glue). The tendency to foam is greatest in relatively clean waters and diminishes as the amount of pollution increases. The author has not noticed the presence of foam in the North Saskatchewan River in the vicinity of Edmonton.

Radioactivity has recently come to the fore as a potentially dangerous form of river pollution. Since there are no atomic energy research establishments in the vicinity of Edmonton, there is not a problem concerning the production of large volumes of radioactive waste waters. The use of artificially produced isotopes for research in hospitals and industry may increase the volume of radioactive waste waters.

Taste and odour are considered as physiological pollution. Industrial wastes contain many chemical compounds which impart a characteristic and unpleasant taste to water (e.g. salts, iron, manganese, free chlorine, hydrogen sulphide, phenols, and unsaturated hydrocarbons). Many of these substances can be removed by conventional water purification processes. However, Besozzi and Vaughn have reported that it was practically impossible to produce economically a drinkable water free from taste and odour at Whiting, Indiana.[26] Lake Michigan, from which the town takes its water supplies, receives considerable pollution

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[26] L. Besozzi and J.O. Vaughn, "Experimental Studies of Odour Control at Whiting, Indiana". American Water Works Association Journ., Vol. 41, 1949, pp. 1035-1045. Discussed in The Engineering Index, 1950, p. 1273.

from oil refinery wastes. Rivers polluted by industrial wastes often contain taste-producing substances (e.g. phenols, chlorophenols) which may damage the value of fisheries by imparting unpleasant tastes to fish. Peculiar tastes can also be imparted to water by the decomposition of organic matter, algae, fungi, and filamentous bacteria.

Most unpleasant smells associated with polluted rivers are due to the presence of inorganic and organic compounds of nitrogen, sulphur, and phosphorous, and arise from putrefaction of organic materials present in sewage and industrial wastes. Some of the worst smells are caused by compounds of sulphur, such as hydrogen sulphide. Food processing wastes (which contain high concentrations of nitrogenous organic matter) develop unpleasant smells when stale due to anaerobic decomposition. Other wastes containing organic substances having characteristic odours are wastes including phenols, esters, ketones, aldepydes, organic acids, sulphur compounds, hydrocarbons, and cyanides.

The Environmental Health Services Division, Alberta, considers phenols at a level of five parts per billion and over undesirable in a stream due to the taste and odour which they impart to water. Extremely high phenolics (24 p.p.b.) were monitered in the North Saskatchewan River during the period February 26th to March 8th, 1968. Several complaints were received by the Environmental Health Services Division from downstream users. The causes of tastes and odours during other periods of complaint could

not be definitely established.

In considering biological pollution of rivers, bacteria, viruses, and plants and animals which for some reason are undesirable are included. Biological pollution is often a secondary result of pollution by sewage or industrial wastes. Lieber has reported that excessive growths of the annual freshwater plant, water chestnut (Trapa natans) in streams in the U.S.A. are due to the discharge of untreated effluents, thus causing fish mortality, bad smells, and serving as a breeding grounds for mosquitoes.[27] Many common diseases (influenza) are virus infections. Therefore, the possibility of virus contamination of rivers exists. Most sewage bacteria are relatively harmless. Since pathogenic bacteria are more easily destroyed than either the normal intestinal bacteria or ordinary water bacteria, it is inferred that if organisms of the coliform group, which can be easily detected and counted, cannot be found, then the pathogens must also be absent.

Maximum values of the most probable number of coliform bacteria per 100 millilitres are 1,600 at the 105 Street Bridge and over 2,400 at the sampling stations downstream. Without treatment, the water is unsuitable for domestic use and of doubtful condition for recreational use.

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[27] Maxim Lieber, "Control of Water Chestnut Growths". Water Works and Sewerage, Vol. 89, 1942, pp. 95-8. Discussed in Biological Abstracts, Vol. 16, 1942, p. 3599.

GROUNDWATER SUPPLIES

Quantity

There are several advantages to the development of groundwater supplies rather than surface supplies. Groundwater supplies are generally free of pathogenic organisms. The temperature of these supplies is nearly constant. Generally the temperature is not much above that of the average air temperature. This is an advantage for industrial use purposes. Generally these supplies are non-turbid and free of colour from organic and other materials. The chemical composition is constant and therefore easier to control. Since these supplies are less susceptible to drought, they are more dependable than surface waters. Radioactive as well as biological contamination of these supplies is difficult.

The bedrock formations that underlie most of the Edmonton area are not sufficiently permeable to yield large quantities of groundwater to wells. The only possible source of large supplies of groundwater in the Edmonton area is the sand and gravel deposits that occur in the bedrock channels.[28] In some localities these deposits are well-sorted and permeable and make excellent aquifers while in some places the deposits are impermeable; or sorted, granular

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[28] R.N. Farvolden, "Bedrock Topography, Edmonton - Red Deer Map-Area, Alberta", in R.N. Farvolden et al, Early Contributions To The Groundwater Hydrology of Alberta. Edmonton, 1963, p. 61.

sediments are absent altogether.

A set of preglacial channels exists west of Edmonton as well as toward Fort Saskatchewan. Since there are large deposits of gravel to the west, it is reasonable to explore these for groundwater where quantities of up to one million gallons per day are required.[29] Such a supply would satisfy a town population of over 150,000 and gives scope for industrial development in the Stony Plain area.[30] The prospects of sufficient quantities of groundwater for domestic supplies are good in the pitted outwash delta area south and west of Big Lake, since the thickness of the sand is over fifty feet in most of the area.[31]

On the other hand, a major disadvantage to groundwater development on the prairies is the low rate of recharge. Farvolden has calculated the annual rate of recharge to the groundwater reservoir over a small basin near Devon, Alberta to be 0.031 feet per year or two per cent of the total annual precipitation. This rate may be representative of the rate of recharge over much of the Alberta "parkland" region. He attributes the low rate of recharge to five factors:

1. A low average annual precipitation;
2. A long winter period when no recharge occurs;
3. Slow melting of ground frost in spring which prevents

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[29] Loc. cit.

[30] Edmonton District Planning Commission, The Edmonton District Water Supply, p. 7.

[31] V.A. Carlson, Bedrock Topography and Surficial Aquifers Of the Edmonton District, Alberta, 1967, p. 17.

recharge during spring runoff;

4. High evapotranspiration rates during summer;

5. Relatively impermeable surface materials.[32]

All the farms in the Devon area obtain water from wells, and almost all of them have experienced difficulty in this matter. Very few drill holes encounter either coal seams or sandstone strata of sufficient thickness, extent and permeability to be suitable aquifers. Wells 400 to 500 feet deep generally yield only one quart of water per minute if pumped continuously.[33]

Quality

The chemical properties of groundwater vary from one surficial water-producing zone to another. However, in general the water from buried-valley aquifers ranges from fairly hard to hard. Water from this source can also have a high iron content, although this is not universal. In some cases, a large amount of total solids has been reported.

In the Devon area water from strata over 200 feet deep has a high alkalinity due to the presence of sodium bicarbonate.[34] Since alkalinity increases with depth there is no possibility of obtaining potable water at depths over 500 feet.

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32 R.N. Farvolden, "Rate of Groundwater Recharge Near Devon, Alberta", in R.L. Farvolden et al., *op. cit.*, pp. 98-105.

33 *Ibid.*, p. 100.

34 *Loc. cit.*

Table V illustrates the variety in quality of groundwater deposits near Edmonton.

TABLE V - GROUNDWATER COMPONENTS

Location	Geologic Horizon of Aquifer	Total Solids	Total Hardness	Sulphates	Chlorides
Calmar	Edmonton	1206	140	367	11
Fort Saskatchewan	Recent	670	415	116	20

Location	Alkalinity	Nitrites	Nitrates	Iron	Nature of Alkalinity
Calmar	600	tr	tr	0.2	Bicarb Na Ca Mg
Fort Saskatchewan	355	tr	tr	0.4	Bicarb Ca & Mg

Source: J.W. Foster and R.N. Farvolden, A General Outline of Groundwater Conditions in the Alberta Plains Region, Edmonton, 1958, pp. 20a-20c.

POTENTIAL FOR IMPROVING WATER SUPPLY

It is possible in most watersheds to increase water yields, improve seasonal flow regime, or improve water quality. This may be done by increasing the water supply or by decreasing losses through evapotranspiration. Methods such as cloud seeding to increase precipitation are quite expensive and results to date obtained by cloud seeding operations have not been satisfactory. This is due in large part to a lack of detailed knowledge of cloud physics, the structure of clouds, and the nature of precipitation processes. Investigations testing the effects of seeding with silver iodide crystals from aircraft have been

conducted by the Division of Radiophysics, Commonwealth Scientific and Industrial Research Organization, Australia.[35] Experiments in the Warragamba Catchment area for three years, 1960-62, suggest that precipitation increases are produced by seeding cumulus type clouds, but decreases in precipitation result from seeding stratiform or "indeterminate" clouds. Preliminary results of experiments conducted in New England, New South Wales from 1958 to 1960 suggest positive results from seeding clouds with tops at temperatures lower than $-5^{o}C.$, and occurring in westerly airstreams giving orographic uplift.

Artificial storage in reservoirs may result in increased stream flow in some years. Generally, however, yields will be slightly reduced due to evaporation losses. The use of monomolecular films of high fatty alcohols (e.g. cetyl alcohol) has been proposed to minimize this loss.[36,37] As long ago as 1924, Hedstrand reported on the evaporation reduction effects of these films on water surfaces.[38]

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[35] J.P. Bruce and R.H. Clark, Introduction to Hydrometeorology. Pergamon Press, Toronto, 1966, p. 278.

[36] W.A. Heath, "Cetyl Alcohol for Evaporation Control". Water and Sewage Works, Vol. 105, 1958, pp. 361-362. Discussed in the Engineering Index, 1958, p. 1068.

[37] A.L. Downing and K.V. Melbourne, "Observations on the Use of Cetyl Alcohol for the Conservation of Water". Institution of Water Engineers Journ., Vol. 11, 1957, pp. 438-442. Discussed in the Engineering Index, 1957, p. 970.

[38] G. Hedstrand, "On the Influence of Thin Surface Film on the Natural Evaporation Rate of Water". Journ. Physical Chemistry, Vol. 28, 1924, pp. 1245-1252.

Mansfield's extensive field trials in Australia re-awakened interest in many parts of the world in the potential value of this technique of reducing evaporation from lakes, ponds and reservoirs.[39] Hobbs has listed the qualities which a practical evaporation suppressant must possess: it must be non-toxic to plant and animal life; form a continuous film over the water surface; be able to reconstitute itself after being broken; be relatively impervious to water molecules; and be in a form easily applied to a water surface at a practical cost.[40] The long-chain molecule fatty alcohols, hexadecanol and octadecanol, have been found to most satisfactorily fulfil these conditions. The most practical size of water surface for obtaining useful savings at reasonable costs is a pond of surface area from 0.1 to 1.0 acres. Evaporation reductions of as much as twenty-five per cent from such water bodies have been observed. The problems of forming and maintaining films on large size ponds, reservoirs and lakes have not been satisfactorily solved. It is estimated that improved techniques will permit cost reduction to about $10 per acre-foot in regions of large evaporation by 1980.[41]

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[39] W.W. Mansfield, "Influence of Monolayers on Natural Evaporation of Water". Nature, Vol. 175, 1955, pp. 247-249.

[40] E.H. Hobbs, "Reduction of Evaporation by Monomolecular Films". Proc. Hydrology Symp., No. 2, National Research Council, Ottawa, 1961, pp. 233-240. Discussed by Bruce and Clark, op. cit., p. 285.

[41] Bruce and Clark, op. cit., p. 286.

Experiments with chemicals to reduce transpiration rates of plants have been reported by Smith and Buchholtz.[42] They demonstrated that spraying plant leaves with a solution of atrazine (2-chloro-4-ethylamino-6-isopropylamino-S-Triozine) causes partial closure of stomata and reduction of transpiration from corn by forty to forty-five per cent six hours after application.

Since different types of vegetation require different amounts of water evapotranspiration, it is possible to change the water requirements of an area by altering the type and density of vegetation and thus change the supply of water available for streamflow. Precipitation falling on forested areas is intercepted partially by plant foliage. Part of this precipitation flows down the plant stems, and the rest is evaporated. A very dense, well matured stand of trees will intercept more moisture than a light open stand of bush or trees. Grass or pasture areas will intercept even less moisture. In this manner a heavily forested area loses more moisture by transpiration and this results in less runoff, other factors being equal.

On the prairie a change in vegetation would have little effect on the runoff of the area since most of the runoff from this area occurs during the early spring and is from melting snow. At this time the ground surface is usually frozen and the type of vegetation would have little effect

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[42] D. Smith and K.P. Buchholtz, "Transpiration Rate Reduction In Plants With Atrazine". Science, Vol. 136, 1962, pp. 263-264.

on the amount of moisture retained in the soil profile. Since there is little potential for yield increase in the plains, it is evident that since it is the major source of the North Saskatchewan River flow, the mountain and foothill part of the basin must receive major consideration in planning for watershed management.[43] Since there are differences in the water balance equation patterns in the mountain and foothill region, the physical potential for streamflow improvement varies from one part of the region to another. Bare rock, coarse colluvial deposits, and shallow, stony soils hold little hope for management change. However, widespread glaciofluvial and alluvial deposits may provide water yield, regime, and quality changes with changes in vegetation cover and use. In these areas the creation of small openings in the forest cover to allow more snow to reach the ground surface will increase streamflow. The removal of deep-rooted plants and the preservation of shallow-rooted ground cover increases streamflow. A deep root can draw water from all the soil pores through which it passes while a shallow root can only draw water from its shallow area.

In the back-range areas, precipitation is large every year, and water yields can be increased by cover removal. This removal need not cause serious erosion or flow regime change, since most of the precipitation falls as snow and

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[43] A.H. Laycock, _Water Deficiency and Surplus Patterns In the Prairie Provinces_. Prairie Provinces Water Board Report No. 13, Regina, 1967, p. 88.

melting occurs over a long period due to the cool temperatures at these heights. Summer rainfall is rarely heavy, and natural cover recovers readily in the moist surroundings.

In the front-range and foothill area vegetative cover removal would not produce significant water yield increase because there is little moisture at depth to be saved from evapotranspiration loss. Precipitation in this area varies greatly from year to year, and in the drier years, moisture is not sufficient to penetrate to the deeper soil horizons. In this case clearing could result in critical erosion and flooding since dry periods might be followed by intense rains from tropical marine air masses.[44] (These air masses rarely penetrate beyond the front range.) In addition, the capacity of the cover in this area to protect surfaces from erosion has been reduced by grazing. Watershed improvement in the front-range and foothill area should, therefore, be oriented toward regime and quality improvement and to erosion and flood limitation.

Domestic, municipal, and industrial uses require a stable flow regime. The most effective single way to improve flow regime is artificial storage in reservoirs. This method is relatively expensive, and it is difficult to find suitable sites for storage of large volumes. Improvement of flow regime in the Edmonton area has occurred through the function of the Brazeau River Dam. This method will

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44 Loc. cit.

probably be of increasing importance in the future since large known volumes can be retained for delivery at desired rates when required.

Water quality may be improved through control of vegetative cover. If local surface erosion is kept to a minimum and streamflow variations are moderate, sediment loads are relatively small. Flow regime improvement results in improved water quality as well. The control of municipal, industrial, and agricultural sewage and waste disposal also has a considerable effect upon water quality.

CHAPTER II

WATER DEMAND

In the past, most parts of Canada have had generous supplies of water, and Canadians have come to expect that ample water supplies would always be available to meet their various demands. In recent years, however, there has been a change in outlook, and it is now realized that action must be taken to preserve water quality and to carefully allocate supplies to increasingly competitive demands.[1] For example, the use of water for fisheries in the Fraser River may, in the future, come into conflict with the use of water for hydroelectric development.[2] The amount of water to be consumed or diverted for irrigation in the Prairie Provinces may come into conflict with power development or other water supply requirements.[3] In addition, the use of many of our rivers for recreation conflicts with municipal and industrial demands.

Although water rights are vested in the Crown, water licences are granted for various uses. The licences are granted in perpetuity, but may be revoked if used for other purposes than those for which they were granted. The prov-

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[1] A.H. Laycock, "Water". in John Warkentin (ed.), Canada, A Geographical Interpretation, Methuen, Toronto, 1967, p. 122.

[2] A.F. Paget, "Multi-Purpose Development of the Fraser River". Vol. I, Resources for Tomorrow Conference Background Papers, Ottawa, 1961, p. 325.

[3] E. Kuiper, "The Water Resources of the Nelson River Basin". Vol. I, Resources for Tomorrow Conference Background Papers, Ottawa, 1961, p. 342.

incial governments of the three Prairie Provinces have given priorities to various water uses. These in order of precedence are "domestic", "municipal", "industrial", "irrigation", "water power", and "other purposes". These priorities serve as guide lines for government allocation of water rights on the basis of the most beneficial use of limited supplies.

DOMESTIC WATER USE

The Water Resources Act of the Province of Alberta defines domestic purposes as household and sanitary requirements, fire protection, the watering of livestock, and the irrigation of home gardens not exceeding one acre.[4] In the Edmonton area surface as well as ground water supplies are used for rural domestic purposes. In 1968, forty-five water licences for domestic use and seventeen applications were on file.[5] The annual requirements of the operating licences are estimated at 266 acre-feet of water. Nearly 66 per cent of the licences list a coulee as the source of supply. Other important sources are Whitemud and Blackmud Creeks, the North Saskatchewan River, and Lake Wabamun. The range of use is from one to 109 acre-feet per year, while the yearly average is 6 acre-feet.

Most of the farms and ranches in the Edmonton area are

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[4] Government of the Province of Alberta, The Water Resources Act, Chapter 362, p. 1.

[5] The area included for the discussion of water licences extends from the west shore of Lake Wabamun to the east end of Cooking Lake. It includes the Sturgeon River Basin to the north and extends slightly farther south than Leduc (Figure 7).

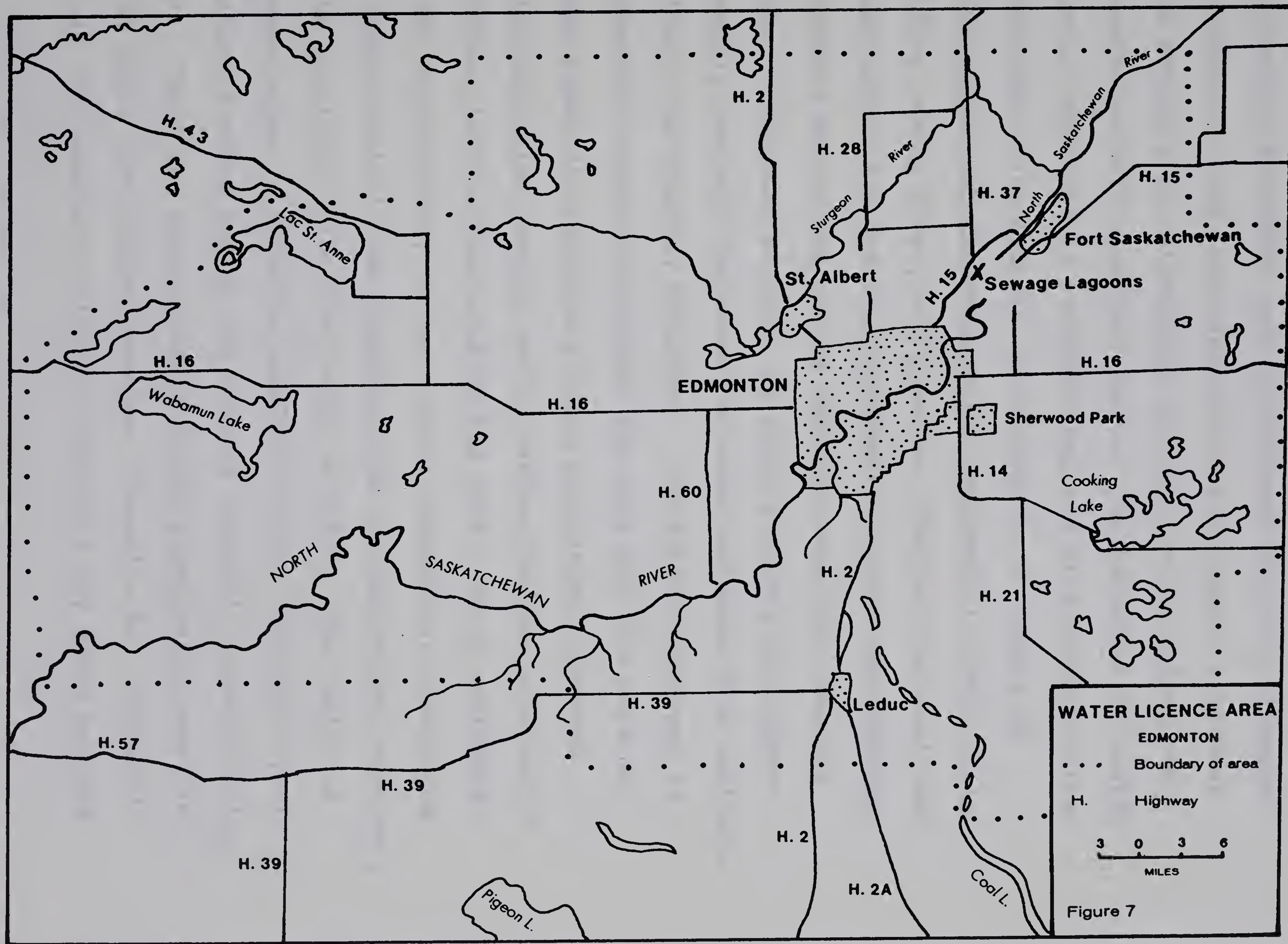
WATER LICENCE AREA
EDMONTON
Boundary of area
H. Highway
3 0 3 6
MILES
EDMONTON
St. Albert
Sherwood Park
Fort Saskatchewan
Sewage Lagoons
Leduc
Cooking Lake
Wabamun Lake
Lac St. Anne
Pigeon L.
Coal L.
NORTH SASKATCHEWAN RIVER
North Saskatchewan River
Sturgeon River
H. 2
H. 2A
H. 14
H. 15
H. 16
H. 21
H. 28
H. 37
H. 39
H. 43
H. 57
H. 60

Figure 7

are mainly dependent upon groundwater from the Edmonton formation. This formation which is of Upper Cretaceous age consists of interbedded soft bentonitic shales and sandstones with some coal seams. The formation is nearly level, often poorly consolidated, and dips gently to the southwest. The bedrock is overlain by a variety of Pleistocene and Recent deposits composed of sands, till, silts, laking clays, and gravels. Most of the rural non-farm population are also dependent on water from bedrock aquifers due to the desire for soft water for domestic use. Withdrawal of water by wells accounts for approximately one-half the amount of water released from aquifers within the Edmonton formation. Artificial discharge is generally uniform throughout the area due to a more or less equal distribution of farm population. Natural discharge also occurs, but in various degrees by means of diffuse leakage over most of the area. It is estimated that approximately 75 per cent of groundwater discharged through wells in the Edmonton area is from bedrock aquifers, the remainder being from wells in drift. The choice of where water is drawn is usually based on the quantity of water required and/or the desired chemical characteristics.

There are approximately 21,000 groundwater users in the rural area around Edmonton. Domenico has estimated that 770 imperial gallons of water per day would be used

by the average farm in the Edmonton area.[6] Based on this estimate, he computes 1,870,000 imperial gallons per day to be used by farms. He estimates the total withdrawal of groundwater at 2,320,000 imperial gallons per day for the non-farm populace, assuming a per capita consumption of fifty imperial gallons.

Groundwater is obtained from sandstones and coal layers in the bedrock to depths of 400 feet. The sandstones and coal layers have a low permeability, and for this reason yields of the wells in these layers are only one to ten gallons per minute.[7] A well of this capacity is suitable for household or stock-watering purposes, but is not satisfactory for irrigation projects since they require larger amounts of water. Safe yields of wells in buried pre-glacial river-channel deposits in the Bon Accord area, in the area east of St. Albert along the Sturgeon River valley, and in the area northwest of Edmonton are 75, 20, and 200 gallons per minute respectively.[8,9] Wells developed in sand and gravel terrace deposits which extend

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[6] P.A. Domenico, Geology and Ground Water Hydrology of the Edmonton Formation in Central Alberta, Canada, unpublished M.Sc. thesis, Syracuse University, Syracuse, 1963, pp. 58-61.

[7] M.G. Gabert, "Groundwater Availability in the County of Sturgeon", in E.B. Swindlehurst, County of Sturgeon Water Conservation and Utilization Survey, Alberta, 1965, p. 40.

[8] Loc. cit.

[9] "Safe yield" refers to the amount of water which may be withdrawn from groundwater supplies so that recharge equals withdrawal.

ten to twenty feet below the river water level can yield 100 gallons per minute or more.[10] Clay deposits have low permeabilities and are generally suitable only for the development of small water supplies.

MUNICIPAL WATER USE

The Water Resources Act of Alberta defines municipal purposes as: household and sanitary purposes; the watering of animals; the watering of streets, walks, paths, boulevards, lawns, and gardens; fire protection; the flushing of sewers; the use of water for the construction of buildings, and of civic works; and other purposes generally served by water within a city, town, or village.[11] Municipal use is largely non-consumptive, so that return flow is almost equal to withdrawal. The paving of streets and walkways has changed major portions of city areas from high soil-moisture storage areas for plant use to very low storage areas.[12] This is only partially offset by withdrawal for the irrigation of lawns, gardens, golf courses, and parks.

The large municipal water users in the prairies obtain their water from the major streams of the region. Most of these streams are of external origin and have larger and more dependable supplies of water as well as a more favorable distribution of flow and better quality than streams

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[10] M.G. Gabert, op.cit., p. 41.

[11] Government of the Province of Alberta, The Water Resources Act. Chapter 363, p. 2.

[12] A.H. Laycock, Water Deficiency and Surplus Patterns in the Prairie Provinces, Prairie Provinces Water Board Report No. 13, Regina, 1967, pp. 83-84.

of local origin.[13] In the vicinity of Edmonton five water licences and five applications are on file for municipal purposes. The City of Edmonton claims two-thirds of these while the remainder belong to Devon and Stony Plain. Municipal water use ranges from 156 to 18,824 acre-feet of water per year, and the annual municipal use licenced to Edmonton totals 20,945 acre-feet.

In the early days of the history of the city of Edmonton water was secured from the North Saskatchewan River by means of the horse and tank wagon method. The price for raw river water was $1.00 for six barrels.[14] A few residents had wells on their premises and a few springs around the town were also used. Fire protection was provided by a volunteer fire brigade with equipment consisting of buckets and pumps.

As early as 1893 several large underground wooden water storage tanks were set in various sections of the town. Frequently, during times of fire, these tanks were found to be empty as a result of leakage. There are repeated references in city council minutes to this problem. A great step forward was taken in 1902 when a by-law was passed authorizing the expenditure for installation of a water and sewer system. The main concern for beginning the

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[13] Idem, Local Water Supplies in the Prairies. Typewritten report of a paper presented at the annual convention of the Canadian Association of Geographers, Saskatoon, 1959, p. 7.

[14] Pers. comm. T. Webb, Edmonton Water Department.

system was fear of fires.[15] At this stage the population of Edmonton had just passed 5,400. The system was installed on the north side of the river east of 102nd Street, and when completed it comprised 6.33 miles of water mains, five miles of sewer mains, and two miles of water and sewer branch services. There were 103 water services and 55 hydrants.

The water system on the south side of the river (then the town of Strathcona) was installed in 1905. The first installation consisted of 1.10 miles of mains. Strathcona had its own power house and pump station, and the water supply was obtained from large wells on the south bank of the river. Independent pump stations were maintained and operated on both sides of the river until the cities amalgamated in 1911.

Since that time the whole city has been supplied from the pump station on the north bank of the North Saskatchewan River. The South Side receives its supply through a submerged main under the river bed and two feed mains near the 105th Street Low Level Bridge. From 1911 to the present the system has been extended in all directions within the city limits to the extent of 968 miles of water mains with a total of 89,885 branch services and 5,908 fire hydrants. In 1967 the construction of a major feed line from the pumping facilities of the city next to the river between 102nd Street and 105th Street to the south-

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15 J.W. Turner, "Waterworks Department". Edmonton's Municipal Utilities - 1928, pp. 30-33.

west section of the city was undertaken. There were also 115 miles of water mains beyond the city limits to serve suburban areas.

The City of Edmonton keeps a balance between its feed mains, reservoir capacity, and treatment facilities in order to provide economic service concurrent with peak demand.[16] Peak demands usually occur during the summer when lawn sprinkling takes place, at six to eight in the evening. The peak use for the city over a five-day period during the summer of 1968 was 135 gallons per person per day, and the peak hour reached 250 gallons per person. The peak day consumption in 1968 reached 63.5 million gallons, and this occurred on June 22nd. The average water demand is only twenty per cent of the five day peak. It is more economical to store water in reservoirs to meet this demand than to build extra pipelines which would only be used for brief periods each year. Water is stored between 11 p.m. and 8 a.m. The City also stores sufficient water to fight two major fires for ten hours: the first at a rate of 10,000 gallons per minute; the second at a rate of 8,000 gallons per minute. In addition, an emergency supply of one average day's use is kept in store.

At present there are three reservoirs operated in the City of Edmonton: a 12,500,500 gallon reservoir at 107 Street and 132 Avenue, in service since 1956; a 12,500,000

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16 Pers. comm., Phil Walker, Superintendent of Edmonton Water Department.

gallon reservoir at 51st Avenue and 75th Street, in service since 1960; and a 5,000,000 gallon reservoir at 74th Street and 144th Avenue which began service in 1968. A 15 million gallon unit is being added to the reservoir at 107th Street and 132nd Avenue. The unit will be in use in 1969, and the project will cost $1,000,000.

Edmonton has three water treatment plants in Rossdale. The oldest section of the first plant went into service in 1948. This plant has a capacity of fifteen million gallons per day. The second plant has a capacity of twenty-five million gallons a day and began operation in 1957. The third plant began operation in 1963 and has a capacity of fifteen million gallons a day. A fourth water treatment plant will be required when the city population reaches 660,000.[17]

At present Edmonton distributes water beyond the boundaries of the city limits to suburban subscribers through pipelines which are consumer-owned. This service provides $3,000,000 a year to the City funds. Water is distributed to the New Town of St. Albert, the Municipal District of Strathcona, and Leduc. Amongst other neighbouring towns, Devon draws its water supply from the North Saskatchewan River, and Fort Saskatchewan obtains its water from buried channel deposits.

As a result of the construction of a fertilizer plant between Redwater and Fort Saskatchewan and the expected

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[17] Pers. comm., Pericles Leonidas, Chief Water Engineer, Edmonton Water Department.

resulting influx of population, the people of the area north-east of Edmonton propose to build a pipeline from an existing water supply main in the County of Strathcona to serve their communities and industry. Fort Saskatchewan has developed its groundwater aquifer to its reasonable limit. Redwater employs a system installed by Imperial Oil in 1949, but this operation cannot cope with a population increase of more than 300 to 500 people.

Fort Saskatchewan and Redwater as well as other towns downstream from Edmonton are discouraged from drawing water from the North Saskatchewan River by the present and potential pollution in the river, originating from the Edmonton area. These towns should, by right of proximity, be able to draw water from the river since it is the recognized riparian right of any land owner whose land is adjacent to a stream.

Sewage disposal is an important use of water for Edmonton. Prior to 1950 the City had four small sewage treatment plants, the first of which was established as early as 1915. These were: by Dawson Bridge on the north side of the North Saskatchewan River; on the South Side near the entry of Mill creek into the North Saskatchewan River; on the present site of the new city plant (east of 50th Street on the South Side); on the North Side at 101st Street. The plant at 101st Street was the first to be built and did not remain in operation for a very long time. The total capacity of the plants was twelve million gallons a day, and consisted

of primary treatment. At that time secondary treatment was not commonly used.

Today the City of Edmonton has two sewage treatment plants as well as a series of sewage lagoons. The remaining small plants have been demolished. The main sewage treatment plant supplies primary as well as secondary treatment, and was one of the first in Canada to supply secondary treatment. It was built in 1957 at a cost of $4.5 million, and has a peak capacity of forty million gallons a day for primary treatment and twenty-five million gallons a day for secondary treatment. The operating cost of the plant is $360,000 a year and the capital cost is $240,000 a year. In summer only primary treatment is supplied. In winter, during low flows, and under ice cover, the primary treatment is augmented with secondary activated sludge treatment.

The smaller plant was built in the 1930s. It services the Garneau district and Windsor Park as far east as Mill Creek, and south to 80th Avenue. This small plant costs the City $40,000 a year to operate while its peak capacity is only five million gallons per day.

Plans are being developed to double the size of the main sewage treatment plant. The original design has reached its capacity use, and it is estimated that with this expansion, service will be satisfactory until 1977. All the sewage will then be taken to the main plant where it can be treated more economically. Tables VI and VII show the effluent characteristics of the sewage treatment plants in 1968.

TABLE VI - EFFLUENT CHARACTERISTICS OF EDMONTON MAIN SEWAGE TREATMENT PLANT, 1968

Month	Flow MIGD	$20^{o}C$, 5 day BOD, ppm	Suspended Solids, ppm	Phenols ppb	Grease ppm	Coliforms per 100 ml. X 10^{-6}
January	25.92	73	71	5	14	1.1
February	27.01	57	109	5	22	2.3
March	27.76	68	109	10	23	4.9
April	25.55	50	75	12	16	1.4
May (a)	25.59	75	104	8	27	--
June	28.13	143	200	81	65	--
July	30.45	122	181	73	59	--
August	30.47	137	175	79	54	24.0
September	30.58	139	179	75	63	--
October(b)	27.95	114	132	115	91	4.6
November	26.60	64	75	12	22	1.5
December	26.43	52	66	7	17	2.3

Source: Calculated from the daily records of the sewage treatment plant.

(a) Secondary treatment terminated May 28, 1968.
(b) Secondary treatment started October 1, 1968.

TABLE VII - EFFLUENT CHARACTERISTICS OF EDMONTON SEWAGE TREATMENT PLANT NO. 3, 1968

Month	Flow MIGD	$20^{\circ}C$, 5 day BOD, ppm	Suspended Solids, ppm	Phenols ppb	Grease ppm	Coliforms per 100 ml. X 10^{-6}
January	2.87	90	38	64	44	14.1
February	3.25	79	76	50	37	34.8
March	3.22	100	101	63	41	2.8
April	3.25	71	70	112	34	11.4
May	3.14	82	83	81	50	14.1
June	2.97	86	95	47	35	--
July	3.24	79	77	72	33	--
August	3.37	87	68	91	34	13.6
September	2.05	98	75	21	22	--
October	2.12	60	61	34	44	33.0
November	2.26	97	104	46	44	22.7
December	2.20	87	102	56	43	54.2

Source: Calculated from the daily records of the sewage treatment plant.

In 1964 several sewage lagoons were built eight miles downstream in the northeast corner of the City in the southeast quarter of Section 3, Township 54, Range 23. They consist of three short-detention aerobic lagoons, and two large anaerobic lagoons. Several of the meat packing plants in the northeast part of the City have been tied to this service. These sewage lagoons also receive domestic wastes from the Beverly subdivision, in the northeast section of the City, and from Sherwood Park, as well as from Namao Airport and Griesbach Barracks. The lagoons are used to store wastes during the winter period of low river flow and are drained to the river each summer during periods of high river discharge, thus reducing the load imposed on the main sewage treatment plant. This is shown by comparison of the average influent analyses in Table VIII. Despite this reduction, the lagoons are operating close to their capacity necessitating an increase in the City's treatment facilities.

IRRIGATION

The important irrigation projects in the Prairie Provinces depend mainly upon the larger streams which have their origin in the mountain and foothill region. The South Saskatchewan River is the most important source since it has an appreciable water supply that flows through the drier parts of the Prairie Provinces, as well as a moderately dependable flow.[18] Local water supplies vary greatly from one year to

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[18] A.H. Laycock, Water Supplies in the Prairies, op. cit., p. 7.

TABLE VIII - EDMONTON MAIN SEWAGE TREATMENT PLANT, AVERAGE INFLUENT ANALYSIS

	Prior to use of lagoons	After the use of lagoons		
	January 1965	January 1966	January 1967	January 1968
Flow, M.I.G.P.D.[1]	23.60	22.49	22.62	25.92
5 day 20°C BOD, ppm	473	349	280	295
Suspended solids, ppm	585	409	341	377
Greases, ppm	223	120	141	117

Source: Information supplied by City Sewage Treatment Department, courtesy of Glen Brown.

[1] M.I.G.P.D. = millions of Imperial gallons per day

the next and have a pronounced spring peak with low flows during the irrigation season.

There are many small irrigation projects in the Edmonton area. Thirty-three licences for this purpose and eighteen applications are recorded. An overall total of 2,453 acre-feet of water is used for irrigation. The annual range is from 3.4 acre-feet to 585 acre-feet, and the average use is 74 acre-feet. Nearly 40 per cent of the withdrawals were from the North Saskatchewan River, 30 per cent from the Sturgeon River, and 20 per cent from coulees. The majority of licences in this area require an eight-inch duty which provides eight inches or two-thirds of an acre-

foot of water on one acre of land.[19]

Under the Prairie Farm Rehabilitation Administration many individual projects are going forward in the Prairie Provinces. During 1963 and 1964, for example, there were forty completed and twenty-three applied for projects in Sturgeon County, northwest of Edmonton.[20] Among these were forty-seven dugouts, eight irrigation projects, and five stock-watering dams, as well as two combination dugout-irrigation projects, and one irrigation-dugout-stock-watering construction. The object of the PFRA program is to help prairie farmers to make the most efficient use of surface water that would otherwise be wasted in large watersheds or through evaporation.

WATER POWER

Local streams in the Prairie Provinces are not suited to hydroelectric power development due to their limited and variable flow, lack of head, and other competitive uses. The Edmonton area is serviced by the Wabamun Power Plant. This power station is located 42 miles west of Edmonton on the shores of Lake Wabamun and adjacent to the Canadian National Railway line. Its electrical energy is generated

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[19] The "duty of water" means the quantity of water that is required to irrigate one acre of land in an irrigation season. The irrigation season in Alberta lasts from the first day of May to the 30th day of September inclusive in each year.

[20] E.B. Swindlehurst, County of Sturgeon Water Conservation and Utilization Survey. Alberta, 1965, p. 24.

by steam. At first the fuel used in the plant was natural gas from the Alexander field, 33 miles northeast of Wabamun, but coal is now used as well as gas. In 1966 the plant used 7,020,987 million cubic feet of gas and 1,174,805 tons of coal.[21] One of the reasons the plant was located on Lake Wabamun is that an adequate supply of cooling water is available from the lake. Calgary Power Ltd. has a licence to use 400,000 acre-feet of water annually from Lake Wabamun.

The Wabamun Plant feeds power into Calgary Power's interconnected system over a 230,000 volt transmission line terminating at the East Edmonton Substation, which serves the major industrial loads in the area as well as the towns, villages, and rural areas around Edmonton. It has a net capacity of 568,000 kilowatts.

The City of Edmonton has had a power plant since 1891. The first small plant was installed on what is now 101st Street. It soon became evident that this site would not accommodate a larger plant, and it was decided to start afresh on the present site in Rossdale where the first installation was made in 1905. The City of Edmonton has a licence for an annual water-power use of 190,000 acre-feet from the North Saskatchewan River. Ninety-five per cent of this is returned to the river. The Edmonton Plant has two circulating water pump-houses which supply the water used for cooling purposes in the power plant. The total pumping capacity of these pump-houses is 270,000 gallons

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[21] Alberta Power Commission, 1967 Annual Report, p. 16.

per minute. The plant's electrical energy is generated by steam, and gas and oil are used as fuel. In 1960 the plant used 14,534,593 million cubic feet of gas and 3,501,553 gallons of oil.[22] Table IX presents some data about demands for the plant.

TABLE IX - CITY OF EDMONTON POWER PLANT, 1967

Factor	Number
Net K.W. Rating	392,000
Peak Load (K.W.)	324,000
Net K.W.H. Generated	1,461,242,000[1]
Number of Customers	101,350
K.W.H. Sold (Less Sales to Other Customers)	1,105,955

Source: Alberta Power Commission, adapted from 1967 Annual Report.

[1] Includes 180,470,000 K.W.H. sold to Calgary Power Ltd.

NAVIGATION

Today navigation for commercial purposes is of little importance in the Prairie Provinces. Historically, however, water transport had a significant function. In the early eighteenth century the Crees of the Edmonton area used the North Saskatchewan River as a transportation route to take their furs for sale to the Hudson's Bay Company at Fort Edmonton. In the latter part of the century the North

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22 Loc. cit.

Saskatchewan River, together with the Nelson River, formed a major waterway by which white men penetrated the Prairie Provinces. Another route inland led from the St. Lawrence River via the Great Lakes and Lake Winnipeg. Edmonton was the end of easy river navigation on the North Saskatchewan and became the bulk breaking point for York boat flotillas from Fort Gary. The shift to Red River carts in the mid 1800s resulted in a decline of river transport. In the late 1800s the use of steamboats revived water transport, and Edmonton became the head of navigation on the North Saskatchewan. Later with the arrival of the railways, there was a decline in steamer traffic. The last steamboat working out of Edmonton ceased operations in 1918.[23]

Diversion of water from northwestern areas to the south and east, through more populated areas, may make navigation more important in the future. River diversion may be accomplished by the long-range plans of the Alberta program of Prairie Rivers Improvement Management Evaluation. This program is based on the fact that abundant future water supplies are located in the northern regions of the province whereas demands are anticipated to occur mainly in the southern and central regions. The PRIME plan proposes development on an individual watershed basis, and outlines

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[23] W.C. Wonders, "River Valley City - Edmonton on the North Saskatchewan". Canadian Geographer, No. 14, 1959, p. 13

projects which may later progressively introduce additional supplies of water from contiguous watersheds to the north.

WILDLIFE

The importance of local water bodies to waterfowl is indicated by the projects of such organizations as Ducks Unlimited. This organization in Canada came into being in 1938 due to the period of drought and duck decline of the 1930s. Its object is to raise funds to be spent on the restoration of waterfowl breeding grounds across the Prairie Provinces. From 1938 to the end of 1960, Ducks Unlimited had built some 228 projects in Alberta with a surface water acreage of 407,820 acreas and a shoreline of some 2,250 miles. This represents approximately 41 per cent of their projects on the prairies, and about 47 per cent of their total project acreage. Two of their projects are located near Edmonton.

RECREATION

Recreational activities associated with local water supplies include swimming, water-skiing, skating, picnicking, fishing, hunting, boating, and camping. Since World War II, there has been a large increase in the demand for recreational facilities.[24] This is reflected in a shorter work week, the paid vacation, improved transport, and the growth of the cities, the main source of this demand.[25] In the Edmonton

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[24] Marion Clawson,"Recreational Resources". in Guy-Harold Smith (ed.), Conservation of Natural Resources, New York, 1950, p. 442.

[25] Loc. cit.

area Big Lake, Lake Wabamun, Elk Island, Pigeon Lake, Bittern Lake, Cooking Lake, Lac Ste. Anne, etc. are popular in meeting this demand.

In most lakes of the Edmonton area, inflow is balanced almost entirely by evaporation from the lake surface. Laycock has suggested that an artificial lake extending twenty-five miles from the north end of Saunders Lake to the south end of Coal Lake be developed for recreational use including boating, fishing, picnicking, sight seeing, and possible cottage development.[26] These lakes are in a spillway channel extending from ten to thirty-five miles south of Edmonton city limits, and they are very shallow. The ratio of drainage area to evaporation surface is one of the best in the area, and precipitation is exceeded by evaporation in most years. In addition, groundwater contributions to this channel are greater than in most lakes because of the deeply-incised valley location. The artificial lake would have a surface area of only six to seven square miles with a shoreline length of fifty to sixty miles. It would not experience the water level fluctuations to which the present lakes are subject. Water quality would be better than that of most lakes in the region because stagnation would be limited by inflow-outflow exchange.

INDUSTRIAL WATER USE

The Water Resources Act of Alberta defines industrial

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[26] The information presented in this paragraph is based on A.H. Laycock, Outline Suggestions and Part of Content Report on "The Evaluation of Lakes in the Edmonton Area for Recreational Purposes". Typewritten report, 9 pp., no date.

purposes as the operation of railways, factories, stores, or warehouses, but it does not include the sale or barter of water for such purposes. Many of the larger industries in the prairies obtain their water from streams of external origin. In several cases these major rivers provide an efficient means of disposal of industrial wastes. Pollution problems of significance exist in the Edmonton area during periods of low water, especially in winter when oxygenation is inhibited by ice cover and low temperatures. There are thirty-four water licences and nine applications on file for industrial water use in the Edmonton area. The annual range of use is from one acre-foot to 42,944 acre-feet. Nearly 35 per cent of the licences are for an annual use of over 1,000 acre-feet. The average yearly water use is 6,953 acre-feet while the median is 300 acre-feet. Table X lists the major municipal and industrial users of the North Saskatchewan River in the vicinity of Edmonton with the purpose of use.

Water is an essential requirement for the operation of most industries. It is used for a multiplicity of purposes: solvent, component, cooling medium, heat, transport, etc. Large quantities of water are required for the manufacture of different products. However, the quantity required to produce one unit of production may vary greatly in the same type of industry, depending on the process used and on the recovery system available. A large part of the water used by industry is not consumed. It is neither, for example,

TABLE X - MAJOR USERS OF THE NORTH SASKATCHEWAN RIVER

MUNICIPAL USER	PURPOSE OF USE
Town of Rocky Mountain House	Water supply and sewage disposal
Town of Drayton Valley	Sewage disposal
City of Edmonton County of Strathcona	Water supply and sewage disposal. Snow dumping. Cooling water for power plant
City of Edmonton Sewage Lagoons	Waste storage for disposal in summer months
Town of Fort Saskatchewan	Sewage disposal
Redwater	Water supply and sewage disposal
Waskatenau	Sewage disposal
Elk Point	Sewage disposal
INDUSTRIAL USER	
Canadian Industries Ltd. Building Products Ltd.	Waste water disposal
Imperial Oil Ltd. S & L Oil Ltd. British American Oil Co. Chemcell	Water supply and waste water disposal
Sherritt Gordon Mines Ltd. Dow Chemical Ltd. - Fort Saskatchewan	Water supply and waste water disposal
Western Chemicals Ltd. - Duvernay	Water supply and waste water disposal
Canadian Salt Co. Ltd. - Lindbergh	Water supply and waste water disposal

Source: Alberta Department of Health, Summary Report, North Saskatchewan River Pollution Survey 1967-1968, pp. 20-21. Municipal water users are included in this table as industry is a significant part of municipal water use.

incorporated in the products nor lost through evaporation, and becomes available for re-use. Many industries, by establishing programs of re-use, have substantially reduced the quantities of water needed.

The quality of water is an important concern for many industries as water is used for many purposes which require widely different properties. Variations in the water quality require continuous control, and may affect the quality of the finished product.

There exists a scarcity of data on industrial water use in the Prairie Provinces. The present study was undertaken to find out what patterns in space, time, and operation exist in Edmonton in the use of industrial water.

CHAPTER III

INDUSTRIAL WATER USE

INDUSTRY IN EDMONTON

Although Edmonton is not primarily a manufacturing centre, the city's economy has a definite and important manufacturing function. The manufacturing industries of Edmonton may be divided into two groups: basic and non-basic industries, although few firms are primarily one or the other. The former group includes those industries which contribute to the export activities of the city, mainly serving non-local markets, and thereby bring money into the city. They include those industries which process livestock from the city's hinterland, and consist largely of meat-packing and slaughtering plants and closely associated activities. They also include those industries which process petroleum and natural gas from nearby fields to produce a variety of chemicals and chemical products. An increase in the basic activity of the city leads to an increase in the non-basic sector. The non-basic industries include those serving local markets. In Edmonton primarily non-basic industries are represented in all manufacturing groups and include most of the industry.

Tables XI and XII show the distribution of the value added by manufacture in Canada. The grouping for Canada was made from a list of the forty leading industries. In Table XII the leading industry groups in Edmonton are

represented. The relative importance of the various manufacturing industries in Edmonton can be seen by a comparison of the value added in Edmonton with the national values. In the food and beverage industries as well as the

TABLE XI - VALUE ADDED IN MANUFACTURING, CANADA, 1961

Industrial Group	Value added (thousands of $)	Per cent of total value added
Food and beverages	1,247,663	11.6
Clothing	245,994	2.3
Wood	309,662	2.8
Furniture and fixtures	103,416	.9
Paper products	918,226	8.5
Printing and publishing	313,355	2.9
Primary metals	938,024	8.7
Metal fabricating	308,024	2.8
Petroleum and coal products	273,516	2.5
Chemicals and chemical products	252,544	2.3
Other major groups	5,771,143	54.7
Value added in all manufacturing[1]	10,682,138	100.0
Non-metallic minerals[2]		3.9

Source: D.B.S., The Manufacturing Industries of Canada, Section G, Geographical Distribution, 1961, Ottawa, 1964.

[1] The value added by manufacture is derived by subtracting the cost of materials, fuel and electricity from the gross value of the products.

[2] D.B.S., The Manufacturing Industries of Canada, Section G, Geographical Distribution, 1959, Ottawa, 1961.

TABLE XII - VALUE ADDED IN MANUFACTURING, EDMONTON METROPOLITAN AREA, 1961

Industrial Group	Value added (thousands of $)	Per cent of total value added
Food and beverages	40,524	24.9
Clothing	6,065	3.7
Wood products	5,041	3.1
Furniture and fixtures	3,642	2.2
Paper products	3,399	2.0
Printing and publishing	8,976	5.5
Primary metals	16,544	10.1
Metal fabricating	13,561	8.3
Non-metallic minerals	15,897	9.7
Chemicals and chemical products	20,245	12.4
Miscellaneous manufacturing	2,562	1.5
Other major groups	25,823	15.9
Value added in all manufacturing	162,280	100.0

Source: D.B.S., The Manufacturing Industries of Canada, Section G, Geographical Distribution, 1961, Ottawa, 1964.

non-metallic minerals the per cent of total value added in Edmonton is twice that of the national totals, while in metal fabricating the per cent of total value added is nearly three times that of the national value. In the chemicals and chemical products group the per cent of total value added is five times the national value.

Tables XIII and XIV show the distribution of employment in selected industry groups in Canada and Edmonton. Nearly a third of Edmonton's manufacturing employment is concentrated in the food and beverage industries. The percentage

TABLE XIII - DISTRIBUTION OF EMPLOYMENT IN MANUFACTURING, CANADA, 1961

Industrial Group	Number employed	Per cent of total
Food and beverages	219,185	15.6
Leather	33,166	2.3
Textile	62,252	4.4
Clothing	91,928	6.5
Wood	98,871	7.0
Furniture and fixtures	35,696	2.5
Paper	101,640	7.2
Printing and publishing	84,265	5.9
Primary metal	90,156	6.4
Metal fabricating[1]	271,058	19.2
Electrical products	84,924	6.0
Non-metallic minerals	47,019	3.3
Chemicals and chemical products	69,510	4.9
Miscellaneous manufacturing	115,195	8.1
All manufacturing	1,404,865	100.0

Source: D.B.S., *Labour Force: Industries, 1961*, Vol. 3, Ottawa, 1963.

[1] Includes machinery and transport equipment industries.

TABLE XIV - DISTRIBUTION OF EMPLOYMENT IN MANUFACTURING, EDMONTON METROPOLITAN AREA, 1961

Industrial Group	Number employed	Per cent of total
Food and beverages	5,300	30.3
Clothing	1,139	6.5
Wood	918	5.2
Furniture and fixtures	598	3.4
Paper	363	2.0
Printing and publishing	1,294	7.4
Primary metal	780	4.4
Metal fabricating[1]	2,843	16.2
Non-metallic minerals	820	4.6
Petroleum and coal products	1,113	6.3
Chemicals and chemical products	1,589	9.0
Other manufacturing[2]	304	1.6
Miscellaneous manufacturing	416	2.3
All manufacturing	17,477	100.0

Source: D.B.S., Labour Force: Industries, 1961, Vol. 3, Ottawa, 1964.

[1] Includes machinery and transport equipment industries.

[2] Includes: tobacco, rubber, leather, textiles, knitting mills, electrical products.

of workers in these industries is nearly double the Canadian average. In Edmonton half of those employed in this category work in meat packing and slaughtering. This is

the largest single manufacturing industry in Edmonton if employment is used as the criterion. The percentage of workers employed in the manufacture of metal is slightly lower than the national average while the percentage employed in the chemical industries is almost double that of the national figure. The wood and furniture and fixtures industries employ a percentage of workers on a par with the rest of Canada. Other industries in Edmonton which employ over 1,000 people are: clothing; printing and publishing; and petroleum products. The percentage of employment in the petroleum products industry is over five times as great as the national average for the petroleum and coal industry.

SAMPLING PROCEDURE

A sample of the industry in Edmonton was selected for further study. After checking the industrial inventory, it was decided that a true random sample of the manufacturers would not give an accurate indication of the water patterns for all branches of industry. There are, for example, a large number of small bakeries in Edmonton. A true random sample would include more of these than necessary for a representative sample of food and beverage industries. A simple random selection of plants would have yielded many more small than large plants because of the skewed distribution of plants by size. In order to obtain a sample representative of the economic importance of Edmonton manufacturing plants, selection proportionate to

size was required. The criterion of size used was the number of employees of each plant. The probability of selecting a plant was made proportionate to the number of its employees. As a result, all "large" plants (those with more than fifty employees) were included in the sample as well as many "small" ones.

Certain industry groups are generally known to have large water demands. It was attempted to include in the sampling known large water users (in absolute terms) such as meat packing plants, breweries, dairies, concrete manufacturers, oil refineries, and steel mills. Printing and publishing houses were excluded from the survey as these have small water demands. More than half these firms in Edmonton hire less than six employees, and the water needed is mainly for human use. A list of possible plants for sampling was drawn up from the Alberta Trade Index, 1967. The list was subsequently stratified prior to the random selection of plants within each group. It was thought that the results from each stratum would be more significant than those for the entire sample. The stratification factor was based on the grouping in the Standard Industrial Classification Manual of the Dominion Bureau of Statistics. The list was also checked to be certain that industries in different parts of the City had been included and that one or two industrial areas had not been isolated, in order to keep the results representative of the industrial portion of the City as a unit. It was deemed necessary not to confine the

survey to within the municipal limits of the City as many important industrial plants which use large quantities of water are located just outside the municipal boundaries in the County of Strathcona. An attempt was also made to keep the proportion of plants in each stratum fairly well in proportion to importance as indicated by number of employees and value added in manufacture. A random starting point was chosen and every sixth firm on the list was selected.

A questionnaire was used to obtain information from the various units. A sample survey of fifteen manufacturers was conducted to see if the questionnaire was clear, unambiguous, and easily answered. An introductory letter was sent to these firms stating the scope and purpose of the study and the approximate time of the visit. As a result of the pilot survey, the questionnaire was modified to include information on the percentage for each source of water supply and the disposal of waste water, and to include the names of by-products recovered from the treatment of waste water.

There are 617 listings for Edmonton in the Alberta Trade Index.[1] Of these, 156 were sampled with a total response of 107 (68 per cent). Although the questionnaire was not designed as a mail survey, thirty mail questionnaires were sent out to compare the rate of response. The questionnaires delivered personally had a much higher rate of response,

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[1] Alberta, Department of Industry and Development, Alberta Trade Index, 1967, Edmonton, 1967.

slightly over 75 per cent. Those delivered by mail received only a 40 per cent response and almost half of these required the sending of a second questionnaire to the firms involved. Many of the plants visited requested that the questionnaire be left with them, to be mailed on completion. Either the information was not readily available or the person qualified to answer the form competently was busy. Most of these questionnaires were subsequently received. Several manufacturers were very busy and could only spare a few hurried moments to answer the form. In several instances the manufacturers, although willing to co-operate, knew very little about the water-use requirements and habits of their plant and had never really considered the firm's water use.

CRITIQUE OF THE QUESTIONNAIRE

The purpose of the questionnaire was to determine the practices of industry in Edmonton with respect to water use and waste water disposal. The first part of the study was designed to provide background information about each company that would be useful later for classification purposes. Subsequent experience indicated that this section would have been improved by the inclusion of a question on what the firm manufactures, to eliminate rechecking with the Trade Index.

Other questions that might have been added to the second part of the study are: the number of wells; yield of wells; type of aquifer; location of private systems of withdrawal; and whether water intake is metered. It would also

have been interesting to know whether some plants experience periods of water deficiency: the time; duration; and volume of such deficiencies. While it is useful to have water withdrawal figures for several years for comparative purposes to see just how representative the current figure is and what the trends are, it was thought that in most cases these figures would not be readily available, and the increased difficulty in completing the questionnaire this would create would discourage some firms from participation.

In the third part of the questionnaire water quality and treatment in the plant were examined. After several industries had been sampled, it was felt that question "b" was not sufficiently explicit. Uniform water quality does not, for example, necessarily mean the quality required must have certain qualities of temperature, or other physical or chemical characteristics. Since the question is vague, it could only be answered in a broad sense. Even within broad limits the response was sometimes inconsistent. Answers to this question can best be interpreted in light of the replies to the next three questions in the survey.

Part Four provided much difficulty for many respondents. Since water use for various purposes is not metered, the amounts had to be estimated, and a number of manufacurers found even an approximate proportion difficult to estimate. The amount used for make-up water due to evaportation seemed the most perplexing. As for the reuse of water, it would be interesting to know how many times the water is reused

and whether resued water needs treatment, as well as the purpose for which it is used.

The volume of discharge water had to be estimated for Part Five, as waste water is not metered. In many instances, the estimate was arrived at by subtracting from the intake various proportions used for processing; lawn sprinkling, stock watering, etc. It would have been useful to know as well the location, number, size, and capacity of evaporation pits, sewage lagoons, and wells.

It is realized that the terms "moderate" and "essentially complete" for the treatment of waste water in Part Six may be interpreted somewhat differently by various concerns. Terms such as settling, filtration, biological and chemical treatment, etc. would have been more objective. However, after due consideration, it was decided to use the terms employed, as they adequately express the condition of effluents in relation to intake. It was also felt that some industries might be unwilling to disclose specific information on this topic.

In Part Seven of the questionnaire opinions on water quantity and water quality in the area were considered. The possible alternative replies to each question were carefully considered so that there would be no difficulty in choosing or differentiating between any two possible answers. A section on expenses might have been included in the questionnaire to learn the cost of water supply and waste treatment facilities as well as annual operating costs for the treatment of

water supply and waste water. After some discussion it was decided that this topic might not be favourably regarded or honestly answered by many manufacturers, and might jeopardize the chances of having the questionnaire answered. For these reasons the topic was omitted.

RESULTS OF QUESTIONNAIRE

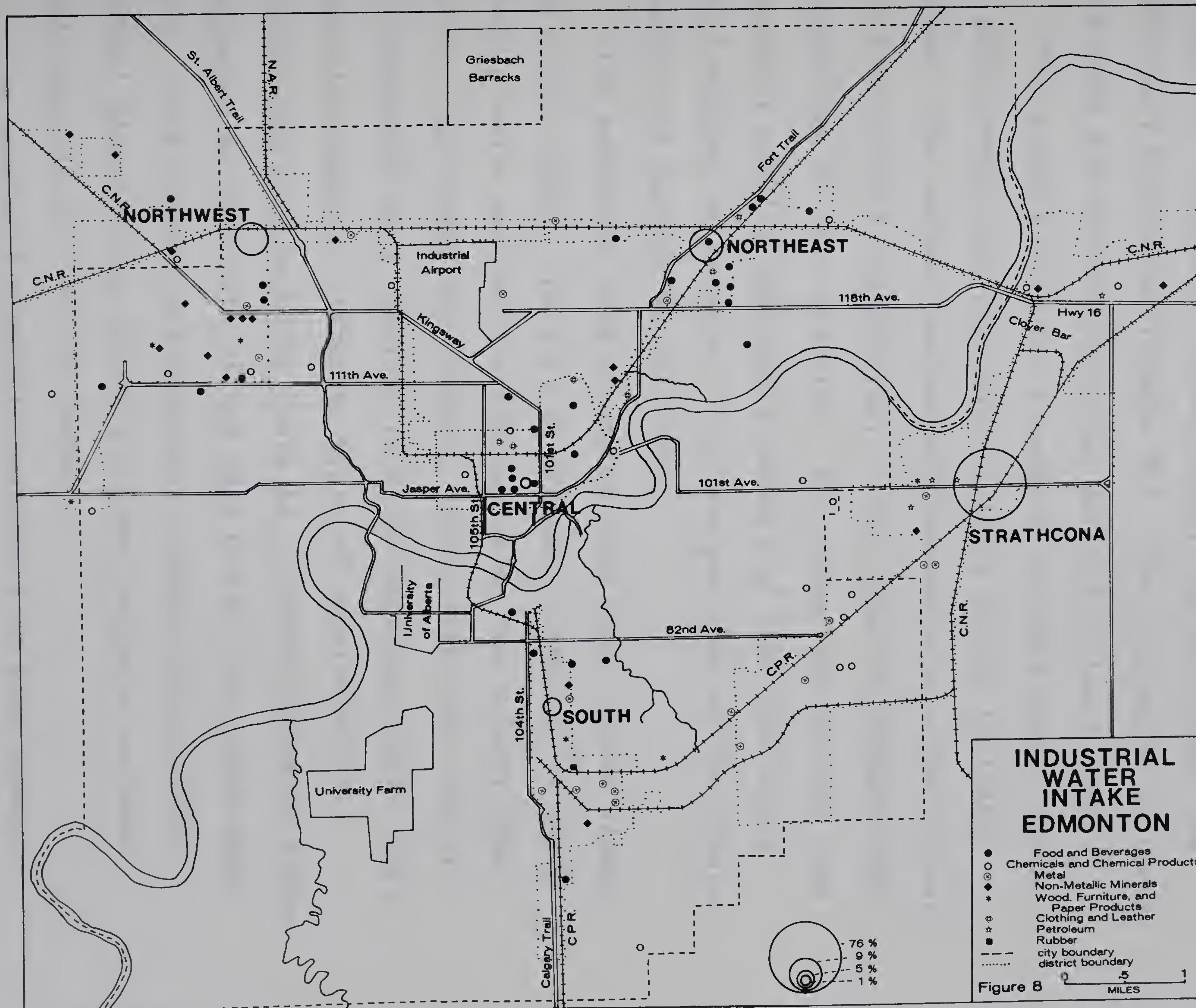
The industries sampled were divided into eight groups (Table XV).

TABLE XV - INDUSTRY GROUPS SAMPLED

Industry group	Per cent of plants studied
Food and beverages	29.0
Clothing and leather	5.5
Metal	17.8
Wood, furniture, and paper products	6.5
Non-metallic minerals	15.9
Petroleum products	3.7
Rubber	.9
Chemicals and chemical products	20.6

Location of Industry

Most of the manufacturing development in Edmonton lies on the outskirts of the city, to the northeast, the north-west, and in an arc from Clover Bar to the Calgary Trail (Figure 8). Much of the industry in the city is located


INDUSTRIAL
WATER
INTAKE
EDMONTON
Food and Beverages
Chemicals and Chemical Products
Metal
Non-Metallic Minerals
Wood, Furniture, and Paper Products
Clothing and Leather
Petroleum
Rubber
city boundary
district boundary
0
.5
1
MILES
76 %
9 %
5 %
1 %
NORTHWEST
NORTHEAST
CENTRAL
STRATHCONA
SOUTH
Griesbach Barracks
Industrial Airport
University of Alberta
University Farm
St. Albert Trail
N.A.R.
C.N.R.
C.P.R.
Fort Trail
Kingsway
118th Ave.
111th Ave.
101st Ave.
82nd Ave.
Jasper Ave.
101st St.
105th St.
104th St.
Calgary Trail
Hwy 16
Clover Bar
Figure 8

close to the railway line. Five manufacturing districts can easily be distinguished as they are widely separated: the central district; the northwest; the northeast; the south; and Strathcona (Figure 8). The boundaries to these divisions are essentially those defined by Lee in 1963.[2]

The central district extends from 100th Avenue north to 107th Avenue and from east of 101st Strret to 111th Avenue. The eastern and western boundaries are 91st Street and 116th Street respectively. Many types of industry are represented in this district. The industries in this zone generally require only small amounts of land and employ small numbers of workers. Fourteen per cent of the plants studied are located in this zone.

The northwest zone stretches from 124th Avenue along the C.N.R. line. There is an eastward extension at 125th Avenue, and a southward extension along the railway line east of the Industrial Airport. Twenty-nine per cent of the responses were received from the northwest zone. This zone also contains different types of manufacturing. Outside the city boundary there is a concentration of large factories to the north of the main C.N.R. line which goes west. More workers are generally required than in the central district but there is a lower employee to land ratio than in the central zone.

The northeast district stretches from 91st Street northeast along the main C.N.R. line. The main industrial

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[2] T.R. Lee, A Manufacturing Geography of Edmonton, Alberta. Unpublished M.A. thesis, University of Alberta, Edmonton, 1963, pp. 58-80.

concentration is between 120th and 130th Avenues. This district is dominated by the meat packing industry. The plants occupy large units of land which are adjacent to one another. Nineteen per cent of the respondents are located in this zone. The southern district extends from Saskatchewan Drive southward along 104th Street (Calgary Trail). The eastern boundary is 75th Street. Sixteen per cent of the plants studied are located in this district. Most of the factories are of a small size, and there is a relatively high employee to land ratio.

The Strathcona district stretches from Highway 16, west of Clover Bar, south to the City boundary at 51st Street. It is a rather specialized manufacturing district. Twenty-two per cent of the plants studied are located in this zone; they are mainly industries which produce chemical, petroleum, and metal products. Some of the largest plants in Edmonton are found in the Strathcona district, and the employee density is the lowest in Edmonton.

Size of Plant

There is a wide range in the number of employees in the manufacturing industries sampled, from one to 925. A division of eight categories is used in this study. The division used is that followed by the Alberta Bureau of Statistics Trade Index, 1967. This grouping indicates clearly the differences in size of the firms in Edmonton according to the number of employees. Thirty-four per cent of the plants sampled have more than fifty employees.

TABLE XVI - SIZE OF PLANTS SAMPLED

Number of employees	Per cent of plants sampled
1-5	12
6-15	24
16-25	14
26-50	16
51-100	14
101-200	12
201-500	4
501-1,000	4

Half of the smallest firms are in food manufacture; the other half is evenly distributed among the metal, clothing, and chemical industries. The sampled firms of this size are about evenly distributed in the various industrial zones with the smallest number in Strathcona. Half of the firms in the following size group are chemical manufacturers. The non-metallic minerals and metal industries make up another 36 per cent. Thirty-six per cent of these plants are in the northwest. Nearly one-third of the industries with sixteen to twenty-five employees apiece are in food production. Metals, wood and paper products each have almost half that proportion. Nearly half these industries are in the northwest and one-quarter in the south. Of the industries with twenty-six to fifty employees each, almost half are food and beverage manufacturers, and nearly thirty

per cent are chemical manufacturers. Thirty per cent of these firms are located in the central area with nearly one-quarter in the northwest and the same amount in the northeast.

Nearly half of the plants which employ 51 to 100 persons apiece produce food and beverages. One-quarter manufacture non-metallic minerals. Almost 60 per cent of these plants are in the two northern industrial zones. Over 60 per cent of the plants which employ 101 to 200 persons are located in Strathcona. Thirty per cent of the industries in this group produce metal products; another 20 per cent produce non-metallic minerals. The plants with 201 - 500 employees each are comprised of a petroleum refinery, a steel mill, a chemical plant, and a cement plant. The first three of these are located in Strathcona; the cement plant is in the northwest. The Great Western Garment Co., Swift Canadian Co. Limited, Chemcell Limited, and Canada Packers Limited employ the largest number of personnel. The first three mentioned are in the northeast zone, and the Chemcell plant is in Strathcona.

Distance from Water Treatment Plant

The Edmonton electrical power generation and water treatment plant at 102nd Street and 96th Avenue, is close to the centre of the City. Most of the manufacturing activity in Edmonton is found on the outskirts of the City in specific industrial districts. Areas of mixed land use exist in the older parts of the City. The rubber, clothing and

food industries are closest to the municipal water treatment plant. The non-metallic minerals industries and petroleum refineries are the farthest from the municipal water treatment plant. The average distance according to the number of employees shows that there is a good distribution of each category for each geographical zone. Plants with more than 100 employees are, on the average, one mile farther from the municipal treatment plant than plants with a smaller number of employees (Figure 9).

Seasonality of Operation

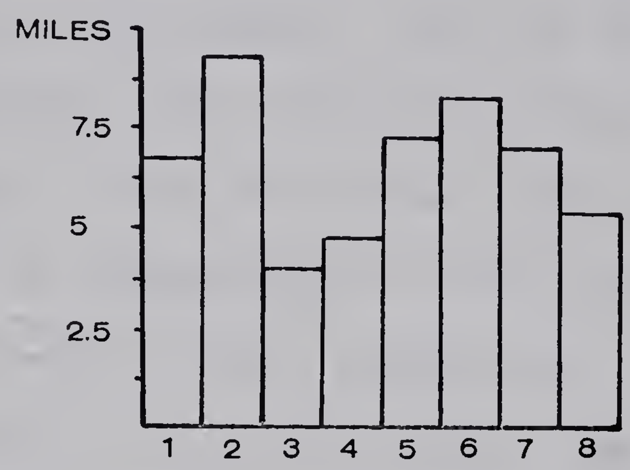
Only 12 per cent of the firms interviewed indicated differences in the seasonality of operation. Nearly 40 per cent of these produce non-metallic minerals. Over 60 per cent refer to the busy season as April to October inclusive. This is the time of full operation for most of the construction industry, where climate is cited as having a strong influence on seasonality of operation. Nearly one-quarter of those indicating seasonality are food and beverage industries. There are also small representations from manufacturers of chemicals, metals, and wood products. Soft drink manufacturers indicated the summer months and December as the busy season. In this case climate as well as holiday occasions influence the operation. Meat packing plants indicated slack periods after the major holidays at Christmas and Thanksgiving, corresponding to periods of low demand.

FIGURE 9

DISTANCE FROM MUNICIPAL WATER TREATMENT PLANT

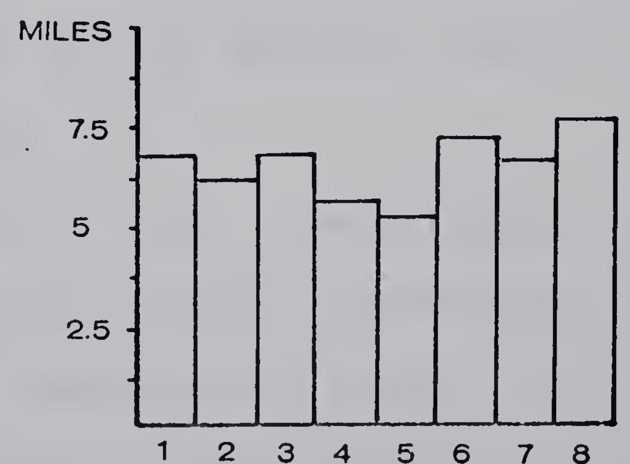
INDUSTRY TYPE

1. Metal
2. Petroleum
3. Rubber
4. Clothing and Leather
5. Wood, Furniture, and Paper Products
6. Non-Metallic Minerals
7. Chemicals and Chemical Products
8. Food and Beverages



SIZE OF INDUSTRY

1. 1 - 5 employees
2. 6 - 15 employees
3. 16 - 25 employees
4. 25 - 50 employees
5. 51 - 100 employees
6. 101 - 200 employees
7. 201 - 500 employees
8. 501 - 1,000 employees



Source of Water Supply

Within the city of Edmonton almost all water is provided through the municipal distribution system. Of the firms surveyed, 19 per cent obtain water from other sources. Of this group, half use a combination of two sources. Six per cent of the manufacturers surveyed obtain water from their own private water plant. Most of these concerns are located in Strathcona and take their water from the North Saskatchewan River. Most are firms which require very large amounts of water in comparison to the rest of Edmonton's industries. Included in this group are: three oil refineries, a steel mill, a chemical plant, and a sand and gravel company. All these plants are beyond or border the city limits and are distant from the city centre. Only the chemical manufacturer takes 100 per cent of its intake water from its own plant. Two-thirds of the concerns also receive water from Edmonton's municipal water works. In these cases the Edmonton works supply between two to twenty-five per cent of the intake.

Eight per cent of the firms studied take water from wells. Half of these produce non-metallic minerals. Except for Inland Cement Industries Limited and Canadian Phoenix Steel and Pipe Limited, these plants are largely small water users. Half of these plants are in the northwest industrial district, and all are located on the outskirts of the City, close to or beyond the city limits. Over 60 per cent of the plants drawing water from wells also use an additional

source. The pattern for three-quarters of the concerns is 80 per cent from the Edmonton system and 20 per cent from company wells.

Five per cent of the plants purchase water from a private water company. Sixty per cent of these receive all their intake in this manner. Twenty per cent draw 95 per cent from company wells, and the remainder take 80 per cent from the municipal source. Generally these firms use extremely small amounts of water, and they involve a variety of industry groups: wood products; metal plating; chemicals; fiberglass; other non-metallic minerals. These firms are also located just within or beyond the city boundary. Canemco Manufacturing Limited which recives 80 per cent of its water from the City, buys distilled water for its industrial process. Northwest Brick and Tile finds the water from company wells satisfactory for the manufacture of its products, but purchases water for human use.

Three per cent of the firms receive water from other industrial firms: a chemical manufacurer and a fiberglass concern purchase 100 per cent of their intake from Chemcell Limited; Imperial Oil Enterprises Limited supplies a wood products firm with over half its intake. These plants are also located adjacent to the city limits in Strathcona.

Quantity of Intake

There is an extremely large range in the quantity of water used per year by different types of industry in Edmonton. While some plants require no water at all for their

manufacturing processes, others need over four billion gallons a year. Chemcell Limited is the largest water user followed by Imperial Oil Enterprises Limited, and Inland Cement Industries Limited. They require 4,094,000,000; 1,134,141,000; and 937,000,000 imperial gallons a year respectively. Generally the petroleum refineries are the largest water users followed by the chemical manufacturers. The latter, however, show great variety within the sampling and, if Chemcell Limited was deleted from the list, the chemical plants would be the smallest water users. The metal industries also show a considerable range in the amount of intake. This is due primarily to the fact that several of the sampled firms, for example Pedlar People Limited, perform only the final stages of manufacture. This firm receives parts which are put together in Edmonton for local sale. This method involves lower freight and shipping costs than the transport of bulky finished products. Some of the firms produce metal products rather than the metals themselves; others do ornamental work.

Most of the clothing and leather producers are small firms with small water demands. Dominion Tanners Limited, which is a large concern employing sixty persons, uses 22,000,000 imperial gallons a year mainly for processing. The wood and paper products industries also show a wide range of water demand. In this case the raw materials are not generally processed in the City. Several of the chemical plants manufacture dry chemicals for use in animal

feeds, and these require no water for manufacturing. Companies which produce paints require solvents rather than water. Plastic manufacturers may or may not require water for cooling purposes. This again depends on whether the firm manufactures the plastics or is only concerned with putting the parts together to form the final product. Most non-metallic mineral products use large amounts of water, for example cement and concrete, although sand and gravel and fiberglass plants require only a quarter as much as the former. Union Carbide of Canada Limited which produces gas compounds uses 12,000,000 imperial gallons a year. Nearly three-quarters of this amount is evaporated in processing. Among the food and beverage manufacturers, the meat-packing plants are the largest water users, followed by the breweries. Within this stratum, the bakeries have the smallest water demands.

Strathcona is the geographic zone with the largest water demand. The petroleum refineries, Chemcell Limited, and several steel mills are all located in this zone. Water demands for the northwest are slightly higher than those for the northeast, although both districts display a great variety in the range of demand. The demand of the southern district is somewhat lower than the two previously considered although quantity of demand is more stable. The central zone has a much lower water demand than any of the other districts. Small clothing firms, chemical manufacturers, small bakeries, and poultry and egg firms are located

in this area. There are, however, some large water-demanding plants in the central zone: dairies and soft drink manufacturers (Figure 10). Generally the larger the amount of intake, the larger is the number of employees (Figure 11). The plants with the largest number of employees are Swift Canadian Company Limited, Great Western Garment Company, Canada Packers Limited, and Chemcell Limited. Except for the garment manufacturer which uses its intake for human use, all require relatively large amounts of water for their manufacturing. The range of variation from the average water intake is greater for plants with large numbers of employees.

Quality of Intake

A numerical rating was accorded to the responses in Question 3,a. A firm stating the quality of water was satisfactory received three points. If the supply was unsatisfactory seasonally two points were given, and one point was given if the supply was unsatisfactory throughout the year. The great majority of firms are well-satisfied with the quality of water. Only 13 per cent of the firms questioned stated that the quality was not satisfactory. Most of the companies stating the supply was unsatisfactory said it was unsatisfactory throughout the year. Two-thirds of those stating quality was unsatisfactory seasonally specified the winter months. They take their supply from the North Saskatchewan River. The food and beverage industries have the highest quality demands. On the three-point scale, the averages

FIGURE 11 INTAKE VS NUMBER OF EMPLOYEES

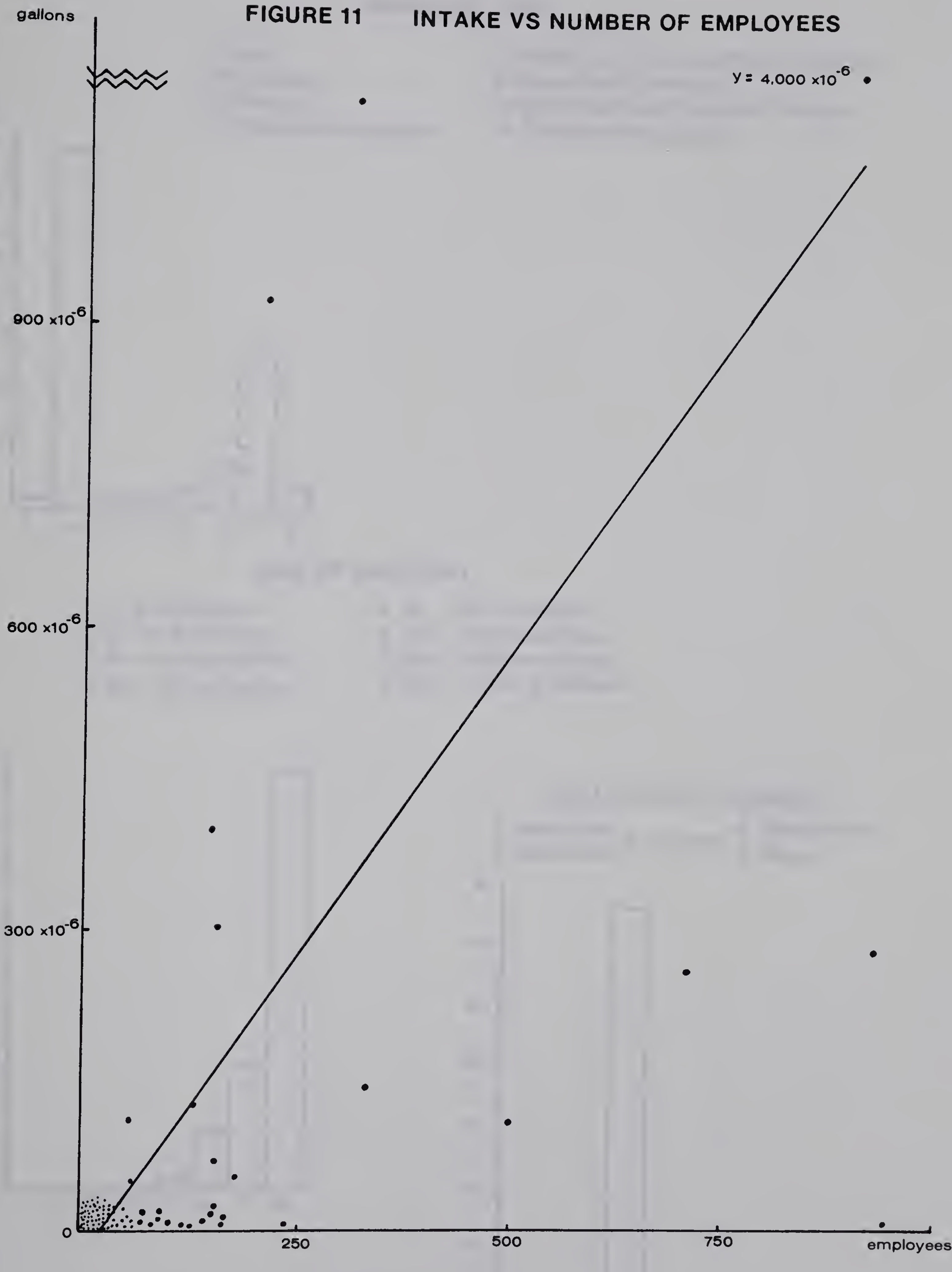
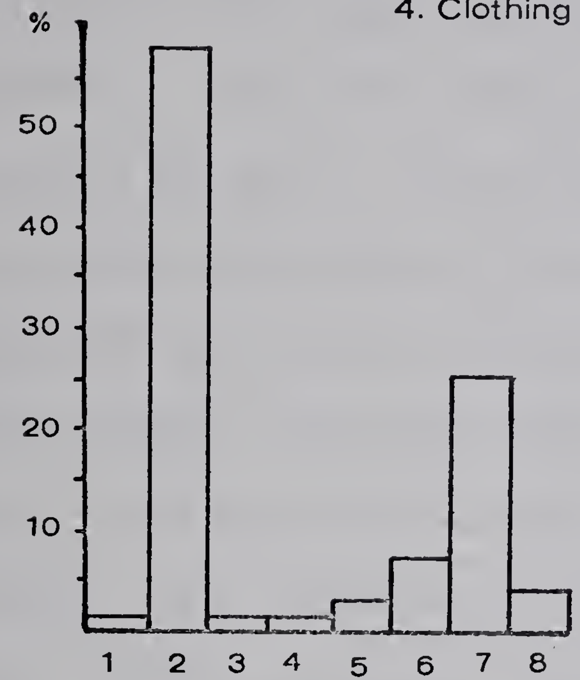


FIGURE 10 PERCENTAGE DISTRIBUTION OF INTAKE

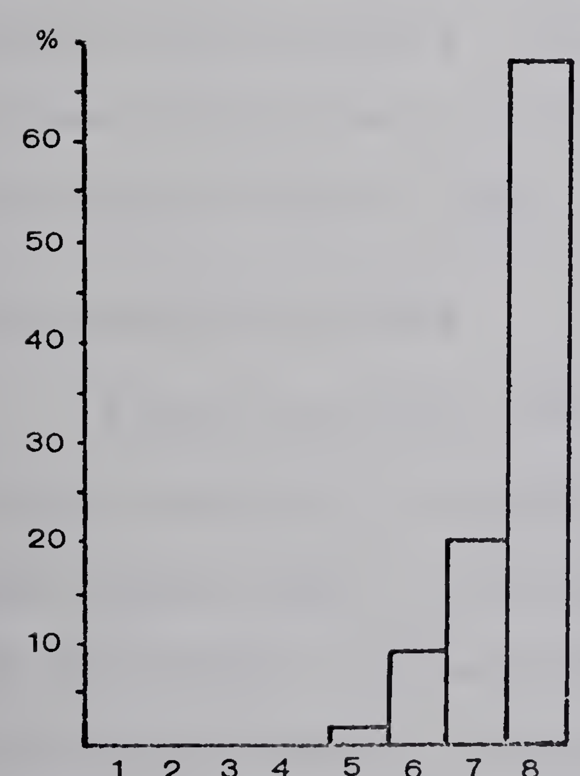
INDUSTRY TYPE

1. Metal
2. Petroleum
3. Rubber
4. Clothing and Leather
5. Wood, Furniture and Paper Products
6. Non-Metallic Minerals
7. Chemicals and Chemical Products
8. Food and Beverages



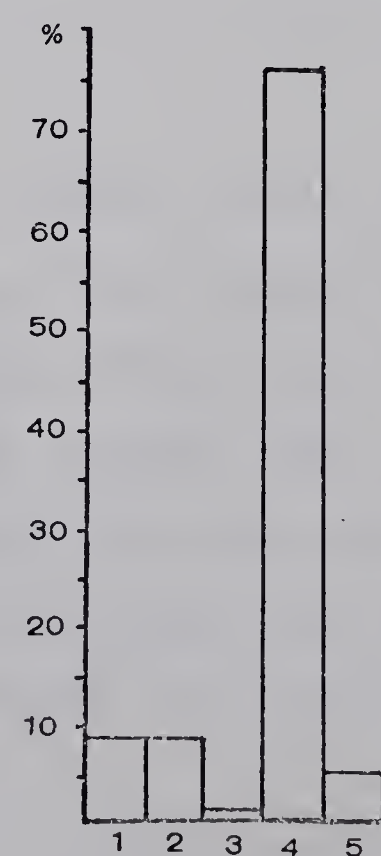
SIZE OF INDUSTRY

1. 1 - 5 employees
2. 6 - 15 emp oyees
3. 16 - 25 employees
4. 25 - 50 employees
5. 51 - 100 employees
6. 101 - 200 employees
7. 201 - 500 employees
8. 501 - 1,000 employees



LOCATION OF INDUSTRY

1. Northwest
2. Northeast
3. Central
4. Strathcona
5. South



for different industrial groups varies from 2.6 to 3.1. (Figure 12a).

Question 3;b was also considered on a numerical scale, a four-point scale in this case. Manufacturers requiring uniform water quality throughout the plant were given two points. One point was given if uniform water quality was needed in part of the plant. If uniform water quality was required throughout the year another two points were added. Only 37 per cent of the respondents require uniform water throughout the plant for the entire year, while 18 per cent need uniform water in part of the plant. On the four-point scale, the averages for each industrial group indicate that the metals group are least demanding about the quality of their water supply, followed by wood, chemicals and clothing industries. (The rubber manufacturer is not considered as this group is somewhat of an oddity with only one plant being represented.) In response to this question, the petroleum refineries are most demanding, where water quality is concerned (Figure 12b).

Treatment of Intake

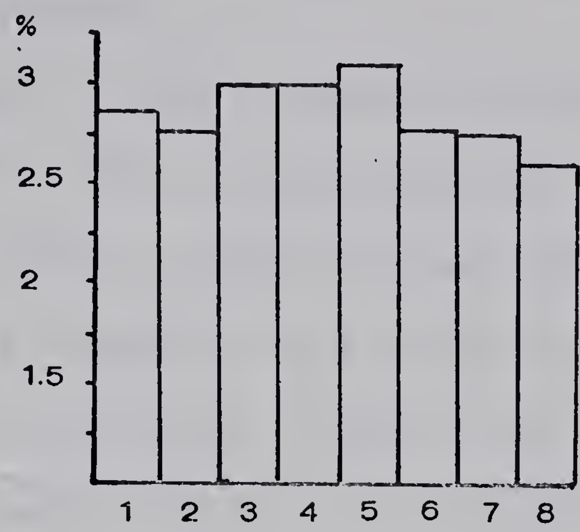
Sixty-seven per cent of the plants supply some form of water treatment. Except for two, they supply treatment for the entire year. Chemcell Limited, which lists five types of treatment, performs three only during the winter months, indicating that the quality of river water during this period is not as high as it is during the rest of the year. The petroleum refineries again are the ones with the

FIGURE 12 QUALITY OF INTAKE

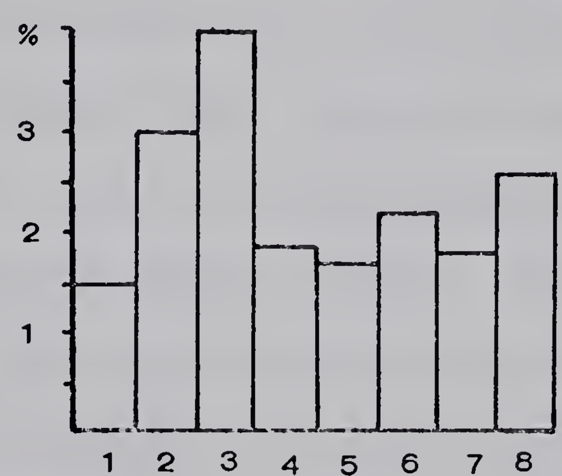
INDUSTRY TYPE

1. Metal
2. Petroleum
3. Rubber
4. Clothing and Leather
5. Wood, Furniture, and Paper Products
6. Non-Metallic Minerals
7. Chemicals and Chemical Products
8. Food and Beverages

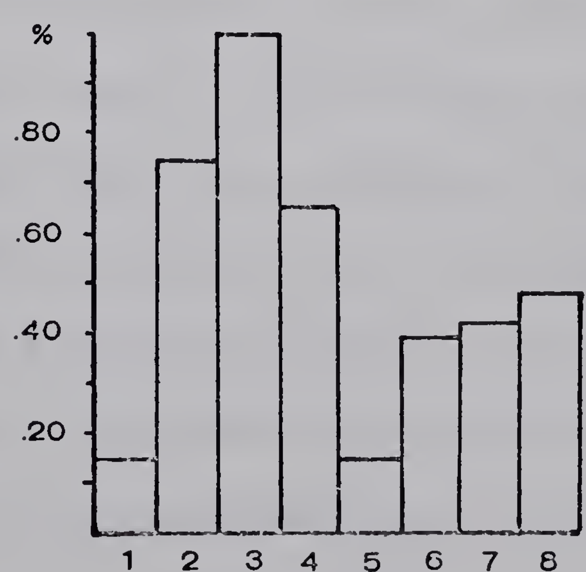
a FIRMS NOT RECEIVING SATISFACTORY WATER QUALITY



b FIRMS REQUIRING UNIFORM WATER QUALITY



c FIRMS PROVIDING WATER TREATMENT



highest degree of treatment. Wood, paper, and metal industries provide the least degree of treatment as the quality received is satisfactory for their purposes (Figure 12c). Two thirds of the clothing and leather plants provide water treatment.

The percentage of water treated varies a great deal from plant to plant. The proportion may be as little as 1 per cent or as great as 100 per cent (Figure 13a). The wood and paper, clothing and leather plants require only small amounts for boiler feed to be treated to prevent scaling. The petroleum refineries provide the highest percentage of treatment. This, however, may be attributed to the fact that they draw water directly from the North Saskatchewan River rather than from the municipal treatment plant. The chemical and food and beverage industries treat a large portion of their intake. Beverage manufacturers have high quality standards for the processing of their products and the washing of bottles. Bakeries provide treatment for quality standards in processing, while meat packing plants generally provide treatment for boiler feed. Fifth Avenue Produce Limited needs very soft water for the washing of eggs. Chemical manufacturers provide treatment for a variety of reasons: to prevent scaling of boilers; for quality standards regarding temperature and processing. Domtar Chemicals Limited, Wood Preserving Division, preheats water for

economic reasons before it is fed to the boiler. Pacific Resins Limited treats cooling water every eight days for hardness, turbidity, and chemicals. Chemcell Limited must provide water treatment since it draws its supply directly from the North Saskatchewan River.

Strathcona is the geographic zone which supplies the highest amount of treatment (Figure 13b). This is as might be expected since the petroleum refineries are located in this district and also because several plants in Strathcona draw water directly from the river. The south is second, due mainly to the large number of beverage industries with high quality standards in this zone. The central and the two northern zones treat similar proportions of their intake.

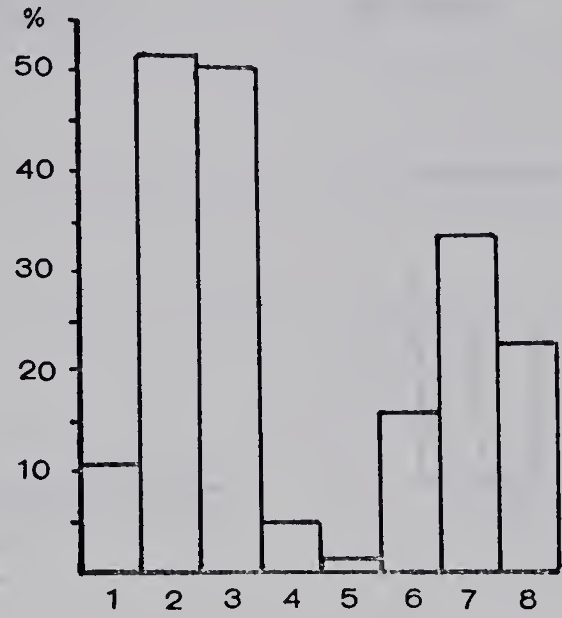
If the percentage of water treated is compared to the number of employees, those firms with 201 to 500 employees provide a much higher degree of treatment than the other categories (Figure 13c). In this division are steel mills, cement plants, oil refineries, and meat packing plants. The next highest group, those plants with 51 to 100 employees, contains a preponderance of beverage manufacturers and some concrete companies. Plants with less than twenty-five employees provide a small degree of treatment as the water received is generally satisfactory for their purposes. Over 55 per cent of those providing treatment in this category are food and beverage concerns; most of the others produce chemicals.

FIGURE 13 PROPORTION OF INTAKE TREATED

a

INDUSTRY TYPE

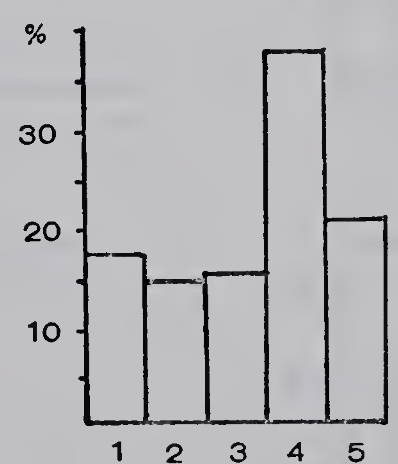
1. Metal
2. Petroleum
3. Rubber
4. Clothing and Leather
5. Wood, Furniture, and Paper Products
6. Non-Metallic Minerals
7. Chemicals and Chemical Products
8. Food and Beverages



b

LOCATION OF INDUSTRY

1. Northwest
2. Northeast
3. Central
4. Strathcona
5. South



c

SIZE OF INDUSTRY

1. 1 - 5 employees
2. 6 - 15 employees
3. 16 - 25 employees
4. 25 - 50 employees
5. 51 - 100 employees
6. 101 - 200 employees
7. 201 - 500 employees
8. 501 - 1,000 employees

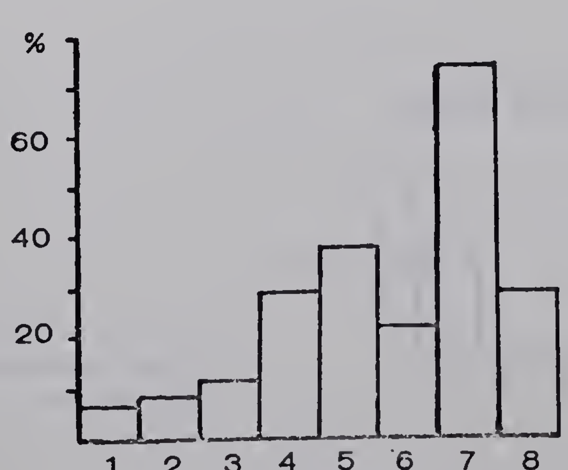
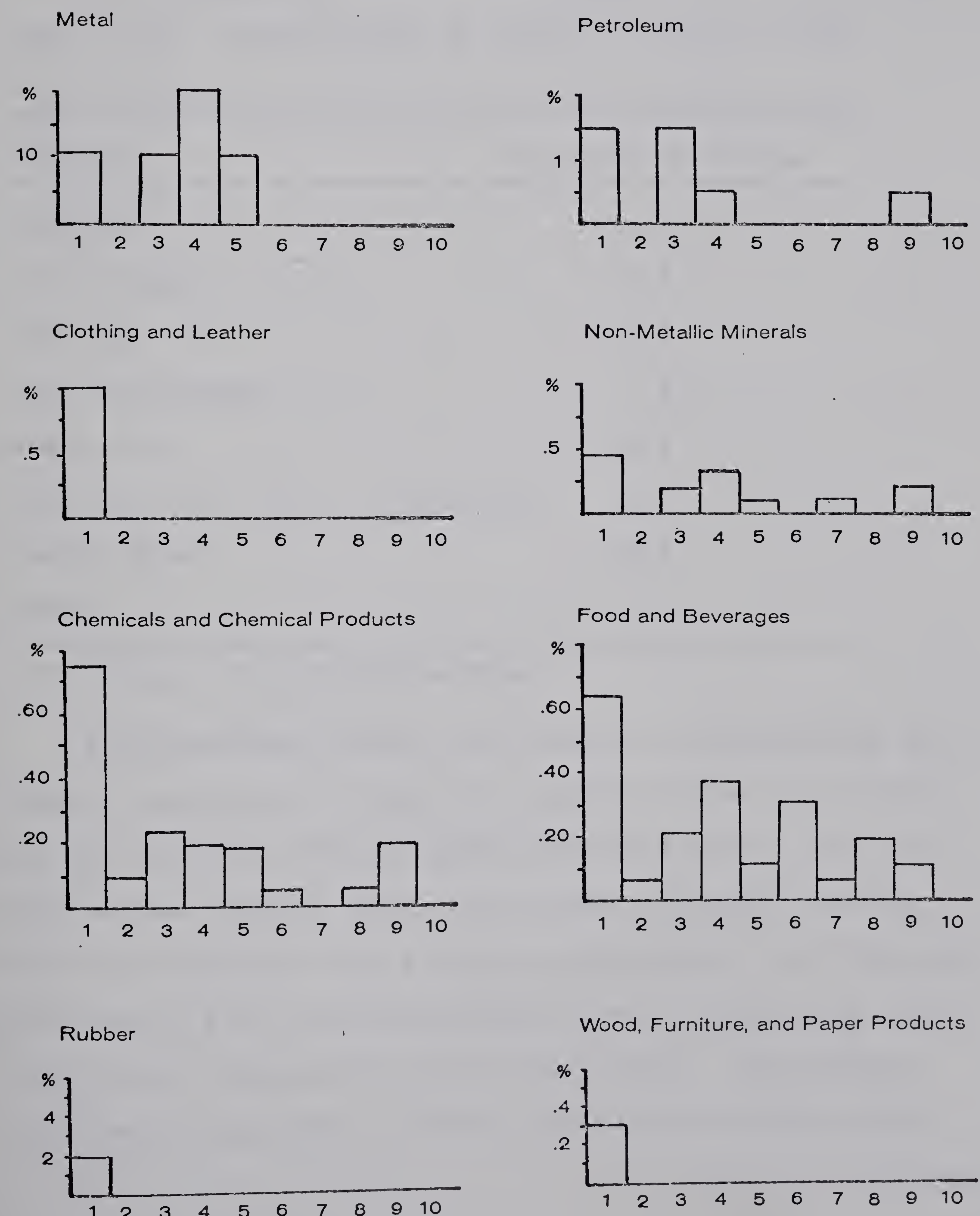


FIGURE 14 REASONS FOR WATER TREATMENT

REASONS FOR TREATMENT

1. Hardness
2. Softness
3. Turbidity
4. Chemical
5. Temperature
6. Taste
7. Colour
8. Odour
9. Biological
10. Other



Use of Water

Table XVII illustrates the proportions of intake used for various purposes by industry in Edmonton. The large percentage of water for human use and boiler feed indicates that Edmonton has relatively low water demands.

TABLE XVII - DISTRIBUTION OF INTAKE, EDMONTON, 1968

Purpose	Per cent of Intake
Cooling	15.7
Processing	27.2
Washing	11.3
Fire Protection	.8
Human Use	22.9
Make-up water due to evaporation	2.1
Boiler Feed	18.7
Other	1.2

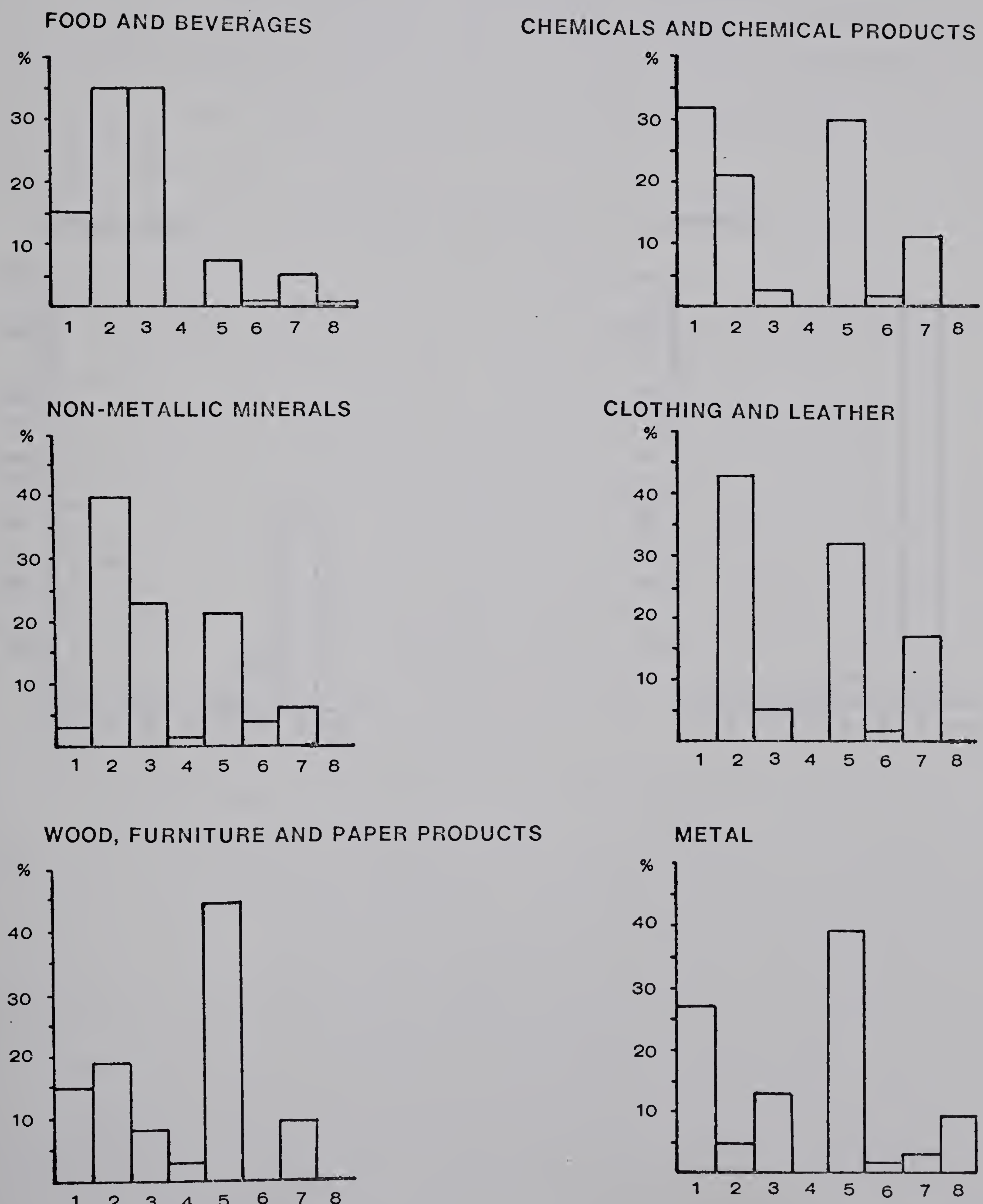
Source: Questionnaire data

The petroleum, metals and chemical industries use the largest proportion of water for cooling while the clothing and non-metallic minerals group use little or no water for this purpose (Figure 15). The leather, tanning, and fur-dressing industries use a large proportion of the intake for processing as do the non-metallic mineral industries. Food and beverage industries are in third place. Generally a very small proportion of water is used for washing except

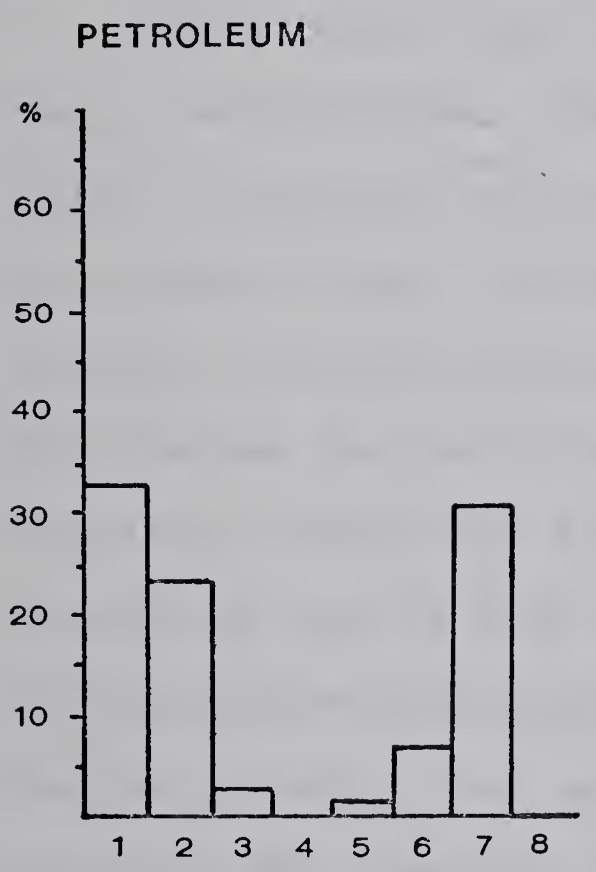
FIGURE 15 AVERAGE USE OF INTAKE

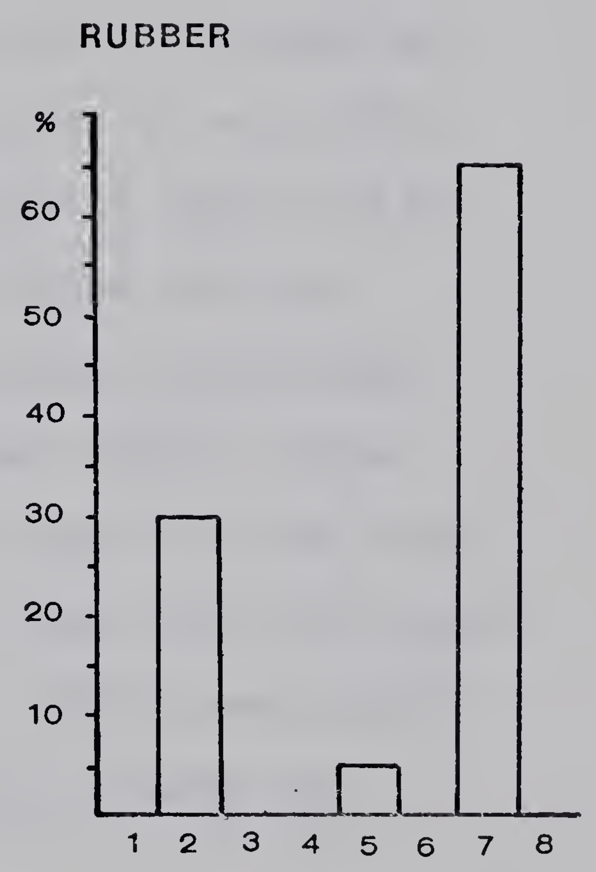
PURPOSE OF USE

1. Cooling
2. Processing
3. Washing
4. Fire Protection
5. Human Use
6. Make-Up for Evaporation
7. Boiler Feed
8. Other



AVERAGE USE OF INTAKE (CONTINUED)





in the case of non-metallic minerals where this amount is nearly one-quarter and food and beverage concerns which use 35 per cent. Very small amounts too are used for fire protection, but the proportion for the wood and petroleum group is slightly higher than for the others. Except for the petroleum industries and the food and beverage industries, a large amount, from 20 to 40 per cent of the average intake, is for human use.

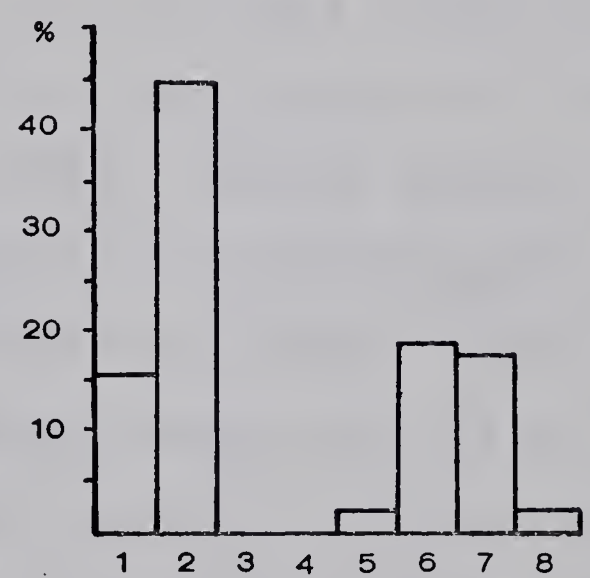
Small proportions were generally stated for make-up due to evaporation. However, in most cases it was difficult to separate this amount from the boiler feed, and to accurately judge this factor. The petroleum and non-metallic mineral groups averaged the largest percentage. The average per cent used for boiler feed shows a wide degree of variation, as little as 2 per cent for the metal industries and as high as 65 and 30 per cent for the rubber and petroleum industries respectively. Other uses stated for water were: lawn sprinkling; testing of tanks and vessels; and watering of livestock.

Only 27 per cent of the firms interviewed reuse water. In most cases this is cooling water and in others water for washing or boiler feed purposes. The amount of water reused varies a great deal from firm to firm. Of those studied, some of the firms which reuse over 90 per cent of their intake are plastic manufacturers, fiberglass concerns, petroleum refineries, and steel mills. Several meat packing plants reuse very small quantities of water, to be specific, less than 10 per cent (Figure 16).

FIGURE 16 INTAKE REUSED

INDUSTRY TYPE

1. Metal
2. Petroleum
3. Rubber
4. Clothing and Leather
5. Wood, Furniture and Paper Products
6. Non-Metallic Minerals
7. Chemicals and Chemical Products
8. Food and Beverages



If the firms which reuse water are considered alone, the average reuse is 43 per cent. The degree of variety involved in the reuse of water suggests there is much scope for additions and improvement in reuse techniques for obtaining more efficeint water use by most industries. More water could be reused for cooling and washing. Water for washing purposes could be reused several times as the quality generally needed is not as high as that for other uses.

Quantity of Discharge

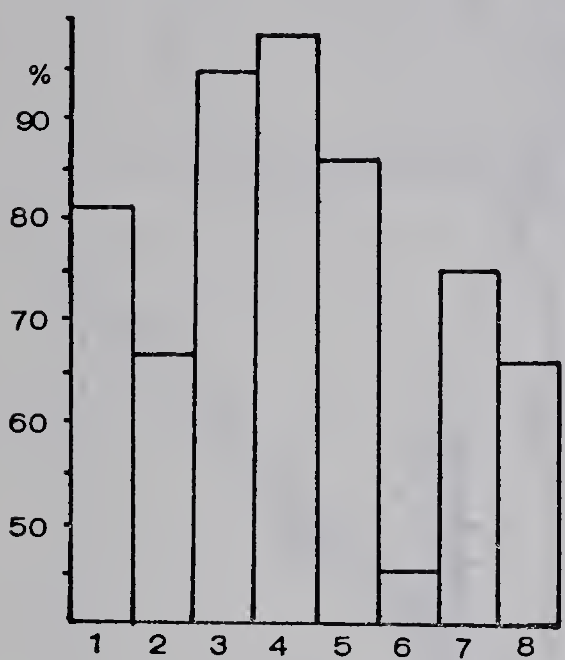
In most industries at least half of the intake water is discharged (Figure 17). The clothing and leather manufacturers consume very little. Larger amounts are consumed by the wood and paper and metal industries, but again this is less than 20 per cent of the intake. Industries of the non-metallic minerals group consume over 50 per cent of the intake (Figure 17). This amount is used up in the processing of cement and concrete. In absolute average amounts, however, the petroleum refineries have the largest discharge, followed by the chemical industries which discharge about half as much as the petroleum refineries. The metal and clothing and leather groups discharge the smallest quantities. Generally, the greater the intake, the greater is the quantity discharged. The averages for the various geographic zones indicate that nearly the same percentage is discharged in each area. In absolute amounts, however, Strathcona has

FIGURE 17 WATER DISCHARGED AND CONSUMED

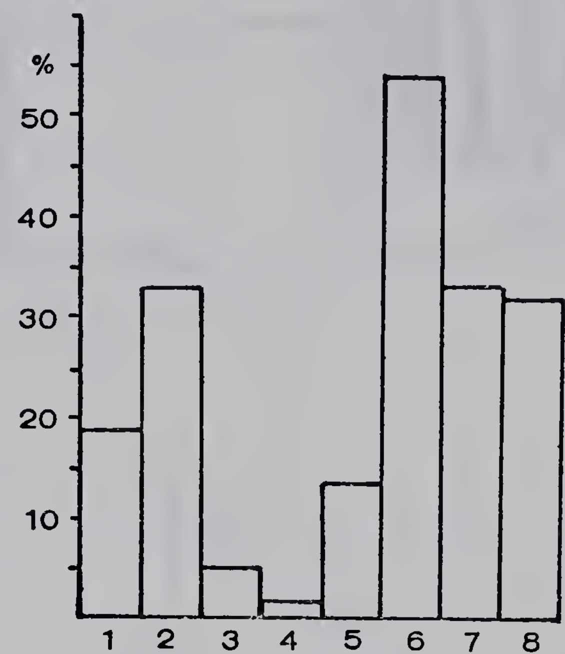
INDUSTRY TYPE

1 Metal
2 Petroleum
3 Rubber
4 Clothing and Leather
5 Wood, Furniture, and Paper Products
6 Non-Metallic Minerals
7 Chemicals and Chemical Products
8 Food and Beverages

DISCHARGED

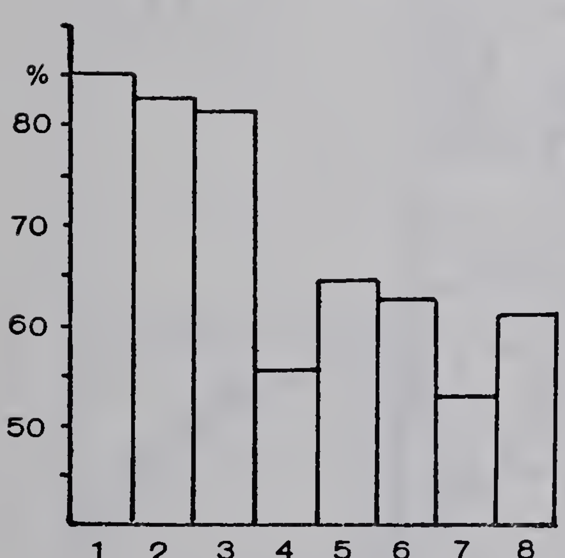


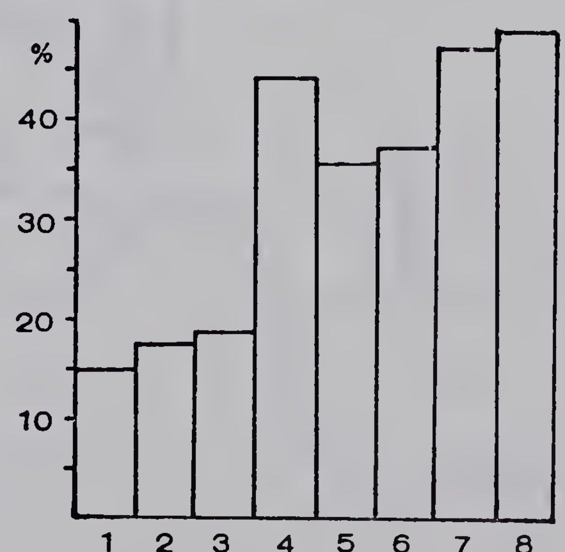
CONSUMED



SIZE OF INDUSTRY

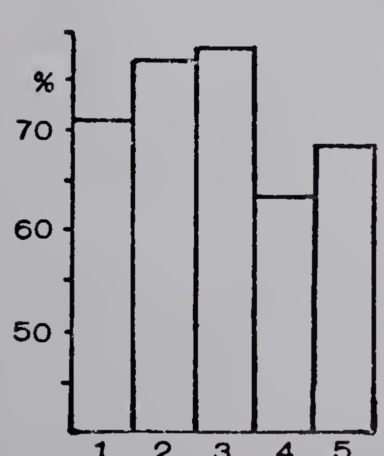
1. 1 - 5 employees
2. 6 - 15 employees
3. 16 - 25 employees
4. 25 - 50 employees
5. 51 - 100 employees
6. 101 - 200 employees
7. 201 - 500 employees
8. 501 - 1,000 employees

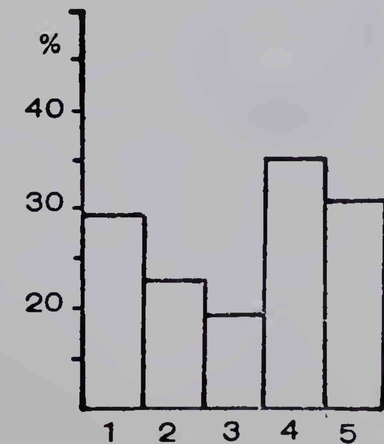




LOCATION OF INDUSTRY

1. Northwest
2. Northeast
3. Central
4. Strathcona
5. South






INDUSTRIAL WATER DISCHARGE
EDMONTON
Food and Beverages
Chemicals and Chemical Products
Metal
Non-Metallic Minerals
Wood, Furniture, and Paper Products
Clothing and Leather
Petroleum
Rubber
city boundary
district boundary
Figure 18
0
.5
1
MILES
74 %
10 %
4 %
1 %
NORTHWEST
NORTHEAST
CENTRAL
SOUTH
STRATHCONA
Griesbach Barracks
Industrial Airport
University of Alberta
University Farm
St. Albert Trail
N.A.R.
C.N.R.
Fort Trail
118th Ave.
Hwy 16
Clover Bar
Kingsway
111th Ave.
101st St.
Jasper Ave.
105th St.
101st Ave.
82nd Ave.
C.P.R.
104th St.
Calgary Trail

a much higher average discharge than the other zones, and the central district has a much smaller average discharge (Figure 18). Again the larger the intake, the larger the amount discharged. The firms with small numbers of employees, twenty-five or less, have a third higher rate of discharge than the firms with more employees. If absolute amounts are considered, the larger the number of employees, the larger is the amount of average discharge.

Quality of Discharge

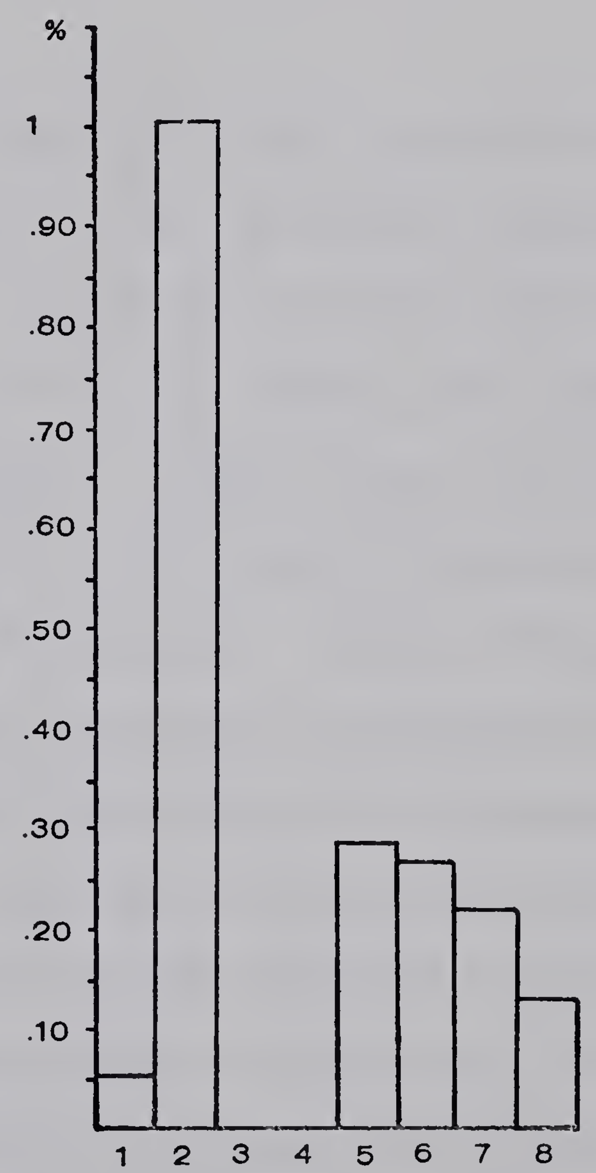
Only 14 per cent of the companies studied provide treatment of effluent before disposal. Considering a two-point scale in which one point is given to a firm providing moderate treatment and two points to a firm providing complete treatment, the petroleum refineries have the highest degree of water treatment (Figure 19). An American Petroleum Institute Separator is used by the petroleum plants. This is a scale which measures the density of the liquid. The oil which floats on top of the water is removed before the waste water is discharged. Sewage lagoons, settling, chemical treatment, and filtration are some of the other methods stated. Several of the meat-packing plants provide treatment of waste water as well as those producing non-metallic minerals. Sixty per cent of the firms which supply waste water treatment are in Strathcona. Most of the others are in the northeast. Nearly 70 per cent of the firms which supply treatment before disposal have over 100 employees.

Very few companies recover useful by-products from the

FIGURE 19 WASTE TREATMENT

INDUSTRY TYPE

1. Metal
2. Petroleum
3. Rubber
4. Clothing and Leather
5. Wood, Furniture, and Paper Products
6. Non-Metallic Minerals
7. Chemicals and Chemical Products
8. Food and Beverages



treatment of waste water. Fats, paper fibres, and petroleum were mentioned. In the case of the petroleum industries which state petroleum products and crude oil, this is not actually a by-product but the main product of the company. Several of the meat-packing plants recover fat which is made into tallow and then used in the manufacture of soap. These fats are also used for the production of meat meals for animal feeds.

Method of Disposal

One-quarter of the manufacturers questioned use outlets other than the municipal sewer system for disposal. Nearly a third of these use a combination of two disposal sources, and of these nearly one-quarter utilize the municipal works for part of their disposal. These firms vary in geographical zone, but none are found in the central district. Over 50 per cent are found in Strathcona. Nearly 20 per cent are in the northwest. These firms are concentrated close to the city limits or just beyond the city boundary. Three-quarters of them have less than fifty employees. Nearly 30 per cent of the companies using disposal systems other than the municipal works are chemical industries with the same percentage for non-metallic minerals, and 20 per cent for metals. All of the employee groups are represented to some degree as using a disposal source other than the municipal works, although firms with 101 - 200 employees constitute over a quarter of these. Another 15 per cent is made up of those with sixteen to twenty-five employees.

Forty-six per cent of these firms stated "other" disposal sources and specified mainly ground surface dumping; a few specified septic tanks and evaporation pits. One-third utilize wells and the North Saskatchewan River. Generally over 80 per cent of the effluent is taken care of by one of the disposal sources: the North Saskatchewan River and municipal sewage works most frequently being named as main sources. Surface water bodies, generally the North Saskatchewan River, are used by nearly a quarter of these firms. All of the firms which use a surface water body for disposal purposes are in Strathcona. These companies each hire over 100 employees and are mainly concerned with the production of petroleum and petroleum products. Wells are used by 17 per cent of these firms and evaporation pits by 15 per cent. The companies which employ wells are also in Strathcona, and are petroleum and chemical manufacturers with over 100 employees.

CHAPTER IV

ADEQUACY OF INDUSTRIAL WATER SUPPLY IN EDMONTON

QUANTITY

Water for industrial and municipal use in Edmonton is supplied by the North Saskatchewan River. The average flow at Edmonton exceeds 20,000 c.f.s. in July, and is as low as 1,000 c.f.s. in January. The operation of the Brazeau River Dam has helped to regulate the difference in seasonal flow pattern and to make the occurrence of a water shortage in Edmonton less likely. Water use in Edmonton averages eighty gallons per person per day or about thirty-three million gallons a day. Industry within the City uses 60 per cent of this amount or about twenty-one million gallons a day. Another twelve million gallons a day is used by industries outside the municipal limits. The average requirement at the above rate of use is 60,225 acre-feet a year. The average annual runoff at Edmonton is 5,611,000 acre-feet.[1] Urban and industrial requirements comprise only a small portion of the average runoff. Despite this small portion, water scarcity may occur. The lowest flow which has been recorded is 220 c.f.s. Present requirements would use only 40 per cent of this rate of flow. However, if Edmonton fulfils its potential to grow to a city of over a million

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[1] Alberta Department of Water Resources and Alberta Power Commission, *Report on Surface Water Supplies and Water Power of Alberta, Their Present and Ultimate Uses*. Edmonton, 1948, p. 28.

people and industry continues to develop, the City would require all of the water in the river if the flow fell to 220 c.f.s. At the same time, it is estimated that at such a stage of development Edmonton would use only 6 per cent of the average annual flow. The great majority of manufacturers questioned believe the quantity of water available in the area to be abundant for their operations. Three per cent considered that it was inadequate. These are firms with small water demands located on the outskirts of the northeast and northwest industrial zones; they are not serviced by the municipal Water Works Distribution System. Five per cent, mainly food and beverage industries, did not know whether the quantity available was adequate or not.

QUALITY

At present the quality of water is a matter for concern. Industrial water use in the Edmonton area has created difficulties for downstream users. The counties adjoining the river cannot offer a supply of potable water to industry locating within their boundaries and adjacent to the North Saskatchewan River due to pollution from upstream. Considerable treatment is required to make the water biologically safe and taste and odour free. Additional industrial development, particularly in the County of Strathcona, will most likely intensify the problem. Most of the manufacturers questioned think the quality of industrial water in the area is satisfactory. Since there are no

major sources of pollution upstream from Edmonton, most city water users are not troubled with a quality problem. Only 4 per cent of the manufacturers stated that the quality of water was not satisfactory for their operations. These are mainly chemical concerns in which the water must be within well-defined temperature limits. The 8 per cent which had no opinion on this matter represent a variety of industrial categories. Only 2 per cent of the manufacturers considered that the quality of industrial water would not be satisfactory in 1988, while one-third indicated that they did not know. Thirteen per cent of the firms indicated that they expect their plant to have disposal problems in 1988. A few of these are meat-packing plants which currently have expenses for waste treatment and expect these to be greater in the future. Other firms will need improved or enlarged facilities. Twenty-one per cent of the manufacturers stated that they did not know whether the plant would have disposal problems in 1988. This response indicates potential waste disposal problems among petroleum refineries, meat-packing plants, dairies, metal and chemical manufacturers.

POTENTIAL MEASURES TO INCREASE ADEQUACY OF WATER SUPPLY TO MEET FUTURE DEMANDS

The storage of water in reservoirs to increase low winter flows would alleviate the pollution situation. For future requirements the provincial government is negotiating with

Calgary Power to build a $30,000,000 dam on the North Saskatchewan River west of Rocky Mountain House. This dam, known as the Big Horn project, is part of the Prairie Rivers Improvement and Management Evaluation program. The dam will be 1,400 feet long and 300 feet high with a storage capacity of over one million acre-feet of water. Not only will this project regulate streamflow, but it will also abate pollution for the water users downstream from Edmonton. A stricter control of industrial waste treatment and effluent disposal in the County of Strathcona would also alleviate the pollution situation. The use of secondary sewage treatment facilities by the municipal sewage treatment system in the summer as well as the winter months would also improve the quality of river water. In the future, more emphasis should be placed on regional approaches to the problem of water quality improvement. Kneese has outlined four concepts which should characterize the approach to water quality management.[2]

The first concept is that of direct interdependence between water quality and water quantity. This interdependence must be recognized and considered in decision-making. The problems and damages related to waste disposal fall mainly upon the subsequent users rather than the dischargers themselves. This is a strong argument for governments to

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[2] Allen V. Kneese, "Approaches to Regional Water Quality Management". Pollution and Environment, Vol. 3, Paper D 30-4, 1967, pp. 2-3.

enforce strict control of waste discharge. In turn the effects of water releases from storage reservoirs during periods of low flow and inter-basin diversion of water must be considered, evaluated, and incorporated in a program of control.

The second concept involves a wide range of alternatives in water quality management. As a regional undertaking, water quality management programs can use large-scale facilities which cannot be efficiently implemented at individual points of waste production. These might include collective facilities for the treatment of wastes from diverse sources, direct treatment of streams, river flow regulation, and diversion of streams.

The third concept for water quality management is that of multi-purpose use. Stream flow regulation for quality improvement may be achieved by reservoirs which at the same time improve the aesthetic and recreational capability of the stream. Certain streams or certain portions of streams might be preserved for recreation demanding high water quality, and others used for waste disposal.

The final concept which should characterize water quality management is that of a comprehensive approach. In this concept development of land use over the complete drainage basin is integrated with water quality management.

A regional approach for water supply and waste disposal in the Edmonton area might include the North Saskatchewan River basin in Alberta. A compulsory

cooperative composed of smaller river basin associations could be formed. These associations would work together to produce an integrated regional system for water quality management as has been done by the Genossenschaften of the Ruhr area.[3] Several towns and cities could be linked to one treatment plant. Cities and industry could utilize collective treatment plants to reduce costs. Industrial wastes can vary substantially in quantity and quality. Changes in these factors can be brought about by the cost to the firm of putting wastes into the water. The quality of wastes would have to be determined at regular intervals. This factor could be established by BOD (biological oxygen demand) and toxicity tests or by potassium permanganate tests the results of which are not influenced by the presence of toxic materials. All the costs associated with an increase in waste delivery could be levied upon the polluting firm and a bounty paid to firms experiencing damages or increased costs.

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[3] A.V. Kneese, The Economics of Regional Water Quality Management. The Johns Hopkins Press, Baltimore, 1964, pp. 160-187.

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APPENDIX A

INDUSTRIAL WATER QUESTIONNAIRE

1. a) Company____
   b) Address____
   c) Number of employees______________________________
   d) Is plant in full-scale operation all year?

   Yes____ No____

   (i) If No, indicate month(s) of operation:

January	____	July	____
February	____	August	____
March	____	September	____
April	____	October	____
May	____	November	____
June	____	December	____

2. a) Source of water supply:

	Percentage from each source
Municipal river plant	______
Private water company	______
Stream or lake	______
Company's own river plant	______
Company wells	______
Other	______

   If Other, please specify:

   b) In the last 12 months, the firm used__________million gallons of water, or__________million gallons per day.

3. a) Is the quality of water satisfactory throughout the year?

   Yes____ No____

(i) If No, specify whether it is unsatisfactory
seasonally____ throughout the year____

b) Is uniform water quality required?

throughout the plant	Yes____	No____
throughout the year	Yes____	No____
in part of the plant	Yes____	No____

c) Is treatment of intake water necessary?
Yes____ No____ Partly____

(i) If Partly, what proportion of total water has to be treated?______________%

(ii) If Yes, indicate reason for and period of treatment:

Reason	All Year	Part of Year (specify months)
Hardness	______	______
Softness	______	______
Turbidity	______	______
Chemicals	______	______
Temperature	______	______
Taste	______	______
Colour	______	______
Odour	______	______
Biological	______	______
Other (specify)	______	______

4. a) During the last 12 months, the firm used water for (please state percentage of total):

Cooling	______	Make-Up Water due to evaporation	______
Processing	______		
Washing	______	Boiler Feed	______
Fire Protection	______	Other (specify)	______
Human Use	______		

b) Did the plant reuse any of the water taken in?
Yes____ No____

(i) If Yes, please estimate the percentage of total intake which was reused:________%

5. a) How much waste water does the plant discharge?

________million gallons a year

b) Where is waste water discharged?

	Percentage to each source
(i) Surface water body	____
Name of water body	________________
(ii) Evaporation pit	____
(iii) Sewage lagoon	____
(iv) Wells	____
(v) Other (specify)	____

6. a) Is waste water treated before disposal?

Yes____ No____

(i) If Yes, is waste water given:

moderate treatment____

essentially complete treatment____

b) If the plant treats waste water, does it recover useful by-products from the treatment?

Yes____ No____

(i) If Yes, name by-products:________________

7. a) Do you consider the supply of water available in this area for the company's operations (please check one):

Abundant____ Not enough____ Don't know____

b) Do you think the quality of industrial water available in this area is satisfactory?

Yes____ No____ No opinion____

c) Do you think the quality of industrial water in this area will be satisfactory in 1988?

Yes____ No____ Don't know____

d) Do you think the plant will have disposal problems in 1988?

Yes____ No____ Don't know____